ELEMENTS

OF

AGRICULTURAL CHEMISTRY

AND

GEOLOGY

BY THE LATE

PROFESSOR J. F. W. JOHNSTON

F.R.S., ETC.

OF DURHAM

AND

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FOURTEENTH EDITION

WILLIAM BLACKWOOD AND SONS

EDINBURGH AND LONDON

MDCCCLXXXVI

TO

JOHN BENNET LAWES, LL.D., F.R.S.

AND

JOSEPH HENRY GILBERT, PH.D., F.R.S.

WHOSE RESEARCHES,

OF MORE THAN FORTY YEARS' DURATION,

HAVE EXTENDED THE BOUNDARIES OF

NEARLY EVERY PROVINCE

OF THE DOMAIN OF SCIENTIFIC AGRICULTURE,

THE TENTH EDITION

OF THIS WORK

IS DEDICATED.

DEDICATION OF THE TWELFTH EDITION.

TO

JAMES DEWAR, Esq.,

M.A., F.R.S.,

FULLEREAN PROFESSOR OF CHEMISTRY IN THE ROYAL INSTITUTION OF GREAT BRITAIN, AND JACKSONIAN PROFESSOR OF NATURAL SCIENCE, CAMBRIDGE UNIVERSITY.

MY DEAR DEWAR,—

To no one could I with greater pleasure dedicate this book than to you.

I know of no British worker in science who has within the same period of time done more than you have to widen its boundaries.

It is men like you who have won for Scotland its reputation as a country of original thinkers and hard workers.

Believe me,

MY DEAR DEWAR,

Yours very faithfully,

CHARLES A. CAMERON.

ADVERTISEMENT

TO THE

TWELFTH EDITION.

THE Editor is pleased to find that the rapid sale of his Tenth and Eleventh Editions of this book has led to the publication of a Twelfth Edition. It is, he ventures to believe, a proof that the work maintains, in the estimation of scientific agriculturists, the position to which its earlier issues attained.

The chief features of the present Edition are an account of the valuable experiments of Messrs Lawes and Gilbert, carried down to the current year, and also of the experiments with phosphatic manures recently made by the Aberdeenshire Agricultural Association, and by some private persons.

PREFACE TO THE TENTH EDITION.

No modern British writer upon scientific subjects attained to greater popularity than the late Professor James F. W. Johnston. His 'Elements of Agricultural Chemistry and Geology,' published in 1842, at once achieved a remarkable success. In five years it ran through as many editions, and was translated into most of the languages of the Continent.

A quarter of a century having elapsed since the death of Professor Johnstón, a thorough revision of his 'Elements of Agricultural Chemistry and Geology' became necessary, and it has been accomplished in this, the tenth edition of the work. In fact the book has been nearly altogether rewritten.

By means of new arrangements in the letterpress, and the addition of fifty pages, a much larger amount of information—rendered neces-

sary by recent progress in scientific agriculture —is given in this edition than in any of its predecessors.

The names and formulæ of chemical substances used in this edition are those which are now universally employed in purely chemical works. The older, and, to most agriculturists, more familiar terms, are, however, occasionally employed, especially when the substances referred to are used for manurial purposes—such as, for example, "nitrate of soda," "sulphate of ammonia," &c. Those who are not acquainted with the "new names" of compounds will find a table at page 14 in which the old designation of every chemical substance referred to in this book is given in juxtaposition with its modern appellation.

In addition to a very copious general index, there is also given an index to 229 authors, whose researches are referred to in the following pages.

In conclusion, it is hoped that a fair outline of the state of our knowledge of scientific agriculture at the close of the year 1876, will be found in this little book.

C. A. C.

Sept. 1877.

PREFACE TO THE FIRST EDITION.

THE scientific principles upon which the art of culture depends, have not hitherto been sufficiently understood or appreciated by practical men. Into the causes of this I shall not here inquire. I may remark, however, that if AGRICULTURE is ever to be brought to that comparative state of perfection to which many other arts have already attained, it will only be by availing itself, as they have done, of the many aids which science offers to it. And if the practical man is ever to realise upon his farm all the advantages which science is capable of placing within his reach, he must become so far acquainted with the connection that exists between the art by which he lives and the sciences, especially of Chemistry, Geology, and Chemical Physiology, as to be prepared to listen with candour to the suggestions they are ready to make to him, and to attach their proper value to the explanations of his various processes which they are capable of affording.

The following little Treatise is intended to present a familiar outline of the subjects treated of more at large in my published LECTURES ON AGRICULTURAL CHEMISTRY AND GEOLOGY. What, in this Work, has necessarily been taken for granted, or briefly noticed, is, in the LECTURES, examined, discussed, or more fully detailed.

Those who wish to put into the hands of the young a still more condensed view of the principles of scientific agriculture, will find it in my CATECHISM OF AGRICULTURAL CHEMISTRY AND GEOLOGY. To most persons, indeed, it will prove advantageous to read the *Catechism* first, and to proceed from it to the *Elements*, and then to the *Lectures*.

DURHAM, *November* 1852.

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Many things which are received as facts in agriculture prove to be more or less untrue when investigated and tested by experiment. Many ascertained facts appear inexplicable to the uninstructed—many even opposite and contradictory—which known principles clear up and reconcile; yet there are many more which only prolonged research can enable us to explain!

2°, *From observations and experiments made in the field or in the laboratory, to deduce principles which may be more or less applicable in all circumstances.*—Such principles will explain useful practices, and confirm their propriety. They will also account for contradictory results, and will point out the circumstances under which this or that practice may most prudently and most economically be adopted.

Armed with the knowledge of such principles, the instructed farmer will go into his fields as the physician goes to the bedside of his patient,—prepared to understand symptoms and appearances he has never before seen, and to adapt his practice to circumstances which have never before fallen under his observation.

To deduce principles from collections of facts is attended with much difficulty in all departments of knowledge. In agriculture it is at present an unusually difficult task. Observations and experiments in the field have hitherto been generally made with too little care, or recorded with too little accuracy, to justify the scientific man in confidently adopting them as the basis of his reasonings. A new race, however, of more careful observers and more accurate experimenters is now springing up. By their aid, the advance of sound agricultural knowledge cannot fail to be greatly promoted

3°, *To suggest improved and perhaps previously unthought-of methods of fertilising the soil.*—A true explanation of twenty known facts or results, or useful practices, should suggest nearly as many more. Thus the explanation of old errors will not only guard the practical man from falling into new ones, but will suggest direct improvements he would not otherwise have thought of. So, also, the true explanation of one useful practice will point out other new practices, which may safely and with advantage be adopted.

4°, *To analyse soils, manures, and vegetable products.* —This is a most laborious department of the duties which agriculture expects chemistry to undertake in her behalf.

a. Soils.—The kind and amount of benefit to be derived from the analyses of soils are becoming every day more apparent. We cannot, indeed, from the results of an analysis, prescribe in every case the kind of treatment by which a soil may at once be rendered most productive, or even improved. In many cases, however, certain wants of the soil are directly pointed out by analysis; in others, modes of treatment are suggested, by which a greater fertility is likely to be produced, — and as our knowledge of the subject extends, we may hope to obtain, in every case, some useful directions for the improvement or more profitable culture of the land.

b. Manures.—Of the manures we employ, too much cannot be known. An accurate knowledge of these will guard the practical man against an improvident waste of any of those natural manures which are produced upon his farm—thus lessening the necessity for foreign manures, by introducing a greater economy

in the use of those he already possesses. It will also protect him against the ignorance or knavery of the manure manufacturer. The establishment of such manufactories, conducted by skilful and honourable men, is one of the most important practical results of scientific progress; and if unscrupulous adulterators cannot be prevented from engaging in this traffic, chemistry can at least detect and expose their frauds.

c. Vegetable products.—In regard to the products of the soil, few things are more necessary than a rigorous analysis of all their parts. If we know what a plant contains, we know what elementary bodies it takes from the soil, and consequently what the soil *must* contain if the plant is to grow upon it in a healthy manner,—that is, we shall know, to a certain extent, how to manure it.

On the other hand, in applying vegetable substances to the feeding of stock, it is of equal importance to know what they severally contain, in order that a skilful selection may be made of such kinds of food as may best suit our purposes, and that no nutritive materials be relatively deficient or excessive.

5°, *To explain how plants grow and are nourished, and how animals are supported and most cheaply fed.*—What food plants require, and at different periods of their growth, whence they obtain it, how they take it in, and in what forms of chemical combination? Also, what kind and quantity of food the animal requires, what purposes different kinds of food serve in the animal economy, and how a given quantity of any variety of food may be turned to the best account? What questions ought more to interest the practical farmer than these!

Then there are certain peculiarities of soil, both physical and chemical, which are best fitted to promote the growth of each of our most valuable crops. There are also certain ways of cultivating and manuring, and certain kinds of manure which are specially favourable to each, and these again vary with every important modification of climate. Thus chemical physiology has much both to learn and to teach in regard to the raising of crops.

So, different kinds and breeds of domestic animals thrive best upon different kinds of food, or require different proportions of each, or to have it prepared in different ways, or given at different times. Among animals of the same species also, the growing, the full-grown, the fattening, and the milking animal, respectively require a peculiar adjustment of food in kind, quantity, or form. All such adjustments, the researches of chemistry and physiology alone enable us accurately to make.

6°, *To test the opinions of theoretical men.*—Erroneous opinions lead to grave errors in practice. Such incorrect opinions are not unfrequently entertained and promulgated even by eminent scientific men. They are in this case most dangerous and most difficult to overturn; so that against these unfounded theories the farmer requires protection, no less than against the quackery of manufactured manures. It is only on a basis of often-repeated, skilfully-conducted, and faithfully-recorded experiments, made by instructed persons, that true theories can ever be successfully built up. Hence the importance of experiments in practical agriculture.

Such are the principal objects which chemistry,

All vegetables, again, as they are collected for food, leave, when burned, a sensible quantity of *inorganic* ash; but of them it forms only a small part. Wood contains about ½ per cent, grain 2 or 3 per cent, straw about 5 per cent; and only in rare cases does the ash left amount to 15 or 20 per cent of the weight of the vegetable substance. Hence, when a handful of wheat, wheat-straw, hay, &c., is burned in the air, a comparatively small weight of matter only remains behind. Every one is familiar with this fact who has seen the small bulk of ash that is left when weeds, or thorn-bushes, or trees are burned in the field, or when a hay or corn stack is accidentally consumed. Yet this ash is very important to the plant, and the study of its true nature throws much light, as we shall hereafter see, on the practical management of the land on which any given crop is to be made to grow. It strikes us also as being important in quantity, when we consider how much may be contained in an entire crop. Thus the quantity of ash left by a ton of wheat-straw is sometimes as much as 330 lb., and by a ton of oat-straw as much as 200 lb., though not generally more than 120 in each case. A ton of the grain of wheat leaves on an average about 45 lb., of the grain of oats about 80 lb., and of oak-wood only 4 or 5 lb.

Animal substances also leave a proportion of ash when burned in the air. Dry flesh and hair leave about 5 per cent of their weight of inorganic ash; dry bones more than half their weight. The burnt ashes of a human adult average only 3½ lb.

Generally, therefore, the soil contains little organic and much inorganic, or mineral matter — the plant

much organic and little mineral—the animal, in its soft parts, little, in its hard or solid parts, much, mineral matter.

CHAPTER II.

CHEMICAL NOMENCLATURE AND NOTATION

Elements and Compounds.—The various kinds of organised, organic, and inorganic matter of which soils, plants, and animals consist, are distributed by chemists into two groups. Those which, by the agency of heat, or by any chemical or other means, can be separated into two or more unlike kinds of matter, are called *compound* bodies; those which cannot be so separated are called *simple,* or *elementary* bodies.

The Chemical Elements.—By the process of *analysis* chalk may be resolved into a white substance termed lime, and a gas called carbonic anhydride. In its turn lime yields a metallic substance (calcium) and a gas termed oxygen, identical with an important constituent of the air which we breathe. Carbonic anhydride in its turn is convertible into oxygen gas, and a black substance, known as carbon, and which is identical in composition with the diamond. Chalk (calcic carbonate) therefore contains the compounds lime (calcic oxide) and carbonic anhydride (carbon dioxide), and its ultimate constituents are calcium, carbon, and oxygen.

All attempts to resolve calcium, carbon, and oxygen

into simpler forms of matter having failed, these bodies are considered to be simple, elementary, or undecomposable substances. Some bodies once regarded as simple are now known to be compound, and probably some of the so-called elements of our time may in the progress of knowledge be decomposed. It is, however, convenient to consider all substances that resist decomposition as elements.

There are known to exist sixty-four elements; and either alone or combined with each other in various proportions they constitute all animal, vegetable, and mineral substances.

Chemical Symbols.—It is often found convenient to use a symbol instead of a name when referring to an element. The symbol is the first letter—with sometimes a second added—of the name of the element. O is the symbol for oxygen, C for carbon, Cl for Chlorine, Ca for calcium, &c. Many of the symbols are taken from the Latin or Latinised names of the elements. For example, Fe from *ferrum*, the Latin name of iron, and Ag from *argentum*, silver.

Definition of Atom and Molecule.—The elements unite with each other, not in every proportion, but in fixed and unvarying quantities. For example, 1 part of hydrogen unites with 35½ parts of chlorine, but never with, say, 43 or 51 parts. The smallest quantity of an element which enters into combination is supposed to be the *relative* weight of its smallest divisible particle, or *atom*. The relative weight of an atom of oxygen is 16, of sulphur 32, of carbon 12—assuming, for the purpose of comparison, that the weight of the atom of hydrogen is 1. Several atoms of one element may unite with one or more

atoms of another element or of several elements. Thus an atom of carbon combines with 2 of oxygen to form carbonic anhydride, and 2 atoms of hydrogen, 4 of oxygen, and 1 of sulphur combine to produce oil of vitriol.

It is believed that most of the elements are incapable of existing in the state of free atoms, and that when their atoms are not in union with those of other elements they enter into combination with each other. Hydrogen in the free state exists in pairs of atoms, and each pair of atoms is termed a *molecule.* H represents the atom of hydrogen, HH its molecule. Certain metals, such as, for example, mercury, can exist in the state of free atoms; hence their atomic and molecular weights are identical. On the other hand, the molecules of phosphorus and arsenic contain each four atoms. The molecule of a *compound* is the smallest quantity which can exist, since it must contain at least two atoms. Although the term atom of a compound often occurs in books, it is not a correct one.

Molecular Volume.—Although there is great diversity in the atomic weights of the elements, there is a remarkable simplicity in their combinations by volume. 1 part of hydrogen unites with 35.5 parts of chlorine, but the two elements combine in equal volumes.

Molecular volumes of the elements, and even of compounds, are with a few exceptions (explainable or likely to be explained) the same. A molecule of hydrogen (HH, or H_2) occupies exactly the same space as a molecule of chlorine gas, hydrochloric acid, or alcohol vapour.

Atomicity.—It is remarkable that some atoms have greater power of combination, so to speak, than others. Thus an atom of chlorine can only combine with one of hydrogen; whilst an atom of carbon can unite with four of hydrogen. The utmost work which an atom of hydrogen can do is only equal to the fourth part of the work which an atom of carbon can accomplish. The elements are arranged into six groups with respect to the relative efficiency of their atoms. Hydrogen, chlorine, potassium, &c., are termed *monads*, or uniequivalent elements; oxygen, calcium, &c., are *dyads*, or biequivalent elements; phosphorus is a *triad*, or terequivalent element; platinum is a *tetrad*, or quadrequivalent element; nitrogen is a *pentad*, or quinquivalent element; and sulphur is a *hexad*, or sexequivalent element.

In the case of compounds, it is found that one molecule of an acid is capable of doing as much work as two or three molecules of another acid. Thus it requires three times as many molecules of nitric acid to unite with bodies to form neutral salts as it does of citric acid, and twice as many as compared with sulphuric acid. Nitric acid is *monobasic*, sulphuric acid is *dibasic*, and citric acid is *tribasic*.

Chemical Nomenclature. — When a non-metallic element unites with a metal, the compound is named in such a way as to indicate its composition. Thus oxygen and iron in combination produce ox*ide* of iron; iodine and lead, iod*ide* of lead; sulphur and sodium, sulph*ide* of sodium,—and so on. When non-metals combine with each other, it is usual to place the name of the more important first, as, for example, chlor*ide* of iodine, sulph*ide* of hydrogen, &c. Acids

are compounds containing hydrogen, and indeed may be regarded as salts of that element. Sulphuric acid is said to be a sulphate of hydrogen; and when the latter and one atom of oxygen (H_2O) are removed, the remaining portion of the compound is termed sulphuric anhydride (SO_3). The substance well known under the name of carbonic acid is really not an acid until it is dissolved in water. In the dry state it is, properly speaking, carbonic anhydride. Every acid has its anhydride, though in a few instances the anhydrides have not been isolated. Sulphuric anhydride combined with the oxides of iron, calcium, magnesium, &c., produces sulphate of iron, calcium, magnesium, &c. Phosphoric anhydride and potash produce phosphate of potassium; nitric anhydride and soda, nitrate of sodium. Some chemists, indeed the majority, term sulphate of sodium, sodic, or sodium sulphate; chloride of potassium, potassic, or potassium chloride. The following table shows the old and new names given to well-known compounds. The formula of each compound is given, but the water of crystallisation, &c., which they sometimes contain, is omitted. Occasionally, however, in the following pages the ordinary or common names of compounds will be used—sulphate of ammonia for ammonic sulphate, oil of vitrol for dihydric sulphate, sulphuretted hydrogen for dihydric sulphide, &c.

TABLE

TRIVIAL OR POPULAR NAME.	OLD NAME.	NEW NAME.	FORMULA.
Oil of vitriol,	Sulphuric acid,	Dihydric sulphate,	H_2SO_4
Aqua fortis,	Nitric acid,	Hydric nitrate,	HNO_3
Spirits of salt,	Muriatic, or hydrochloric acid,	Hydric chloride, or chlorhydric acid,	HCl
Vinegar,	Acetic acid,	Hydric acetate,	$HC_2H_3O_2$
Fixed air, or choke-damp,	Carbonic acid,	Carbonic dioxide, or carbonic anhydride,	CO_2
	Carbonic acid hydrate,	Carbonic acid, or dihydric carbonate,	H_2CO_3
	Anhydrous, or dry sulphuric acid,	Sulphuric anhydride, or sulphuric trioxide,	SO_3
	Anhydrous nitric acid,	Nitric anhydride, or dinitric pentoxide,	N_2O_5
	Anhydrous phosphoric acid,	Phosphoric anhydride, or diphosphoric pentoxide,	P_2O_5
	Monobasic, or metaphosphoric acid,	Monohydric phosphate, or hydric meta-phosphate,	HPO_3
	Bibasic, or pyro-phosphoric acid,	Tetrahydric pyrophosphate,	$H_4P_2O_7$
	Common, tribasic, or ortho-phosphoric acid,	Trihydric phosphate,	H_3PO_4
	Ammonia,	Ammonia,	NH_3
Spirits of hartshorn,	Hydrate of ammonia,	Ammonic hydroxide,	NH_4HO
Potash, or caustic potash,	Anhydrous potassa, or oxide of potassium,	Dipotassic oxide,	K_2O
	Hydrate of potash,	Potassic hydroxide,	KHO
Quicklime,	Oxide of calcium or lime,	Calcic oxide,	CaO
Milk of lime,	Hydrate of lime,	Calcic hydroxide,	$Ca(HO)_2$
Red precipitate,	Protoxide of mercury,	Mercuric oxide,	HgO
Washing soda,	Carbonate of soda,	Disodic carbonate,	Na_2CO_3
Pearl-ash, or salt of tartar,	Carbonate of potash,	Dipotassic carbonate,	K_2CO_3
Sugar of lead,	Acetate of lead,	Plumbic diacetate,	$Pb2C_2H_3O_2$
Common salt,	Chloride of sodium,	Sodic chloride,	$NaCl$
Sal-ammoniac,	Muriate of ammonia, or chloride of ammonium,	Ammonic chloride,	NH_4Cl

Glauber's salts,	Sulphate of soda,	Disodic sulphate,	Na_2SO_4
Sal-enixum,	Bisulphate of potash,	Hydric potassic sulphate,	$HKSO_4$
Gypsum, or plaster of Paris,	Sulphate of lime,	Calcic sulphate,	$CaSO_4$
Epsom salts,	Sulphate of magnesia,	Magnesic sulphate,	$MgSO_4$
Alum,	Double sulphate of potash and alumina,	Potassic aluminic sulphate,	$KAl2SO_4$
Nitre, or saltpetre,	*Nitrate of potash,*	*Potassic nitrate,*	KNO_3
Cubic nitre,	Nitrate of soda,	Sodic nitrate,	$NaNO_3$
Copperas, or green vitriol,	Protosulphate of iron,	Ferrous sulphate,	$FeSO_4$
	Per- or sesqui- sulphate of iron,	Ferric sulphate,	Fe_23SO_4
Calomel,	Subchloride of mercury,	Mercurous chloride,	Hg_2Cl_2
Corrosive sublimate,	Protochloride of mercury,	Mercuric chloride,	$HgCl_2$
Lunar caustic,	Nitrate of silver,	Argentic nitrate,	$AgNO_3$
Bluestone, *or* blue vitriol,	Sulphate of copper,	Cupric sulphate,	$CuSO_4$
Tasteless purging salts,	Common, or rhombic phosphate of soda,	Disodic hydric phosphate,	HNa_2PO_4
	Subphosphate of soda,	Trisodic phosphate,	Na_3PO_4
	Biphosphate of soda,	*Sodic dihydric phosphate,*	H_2NaPO_4
Bone phosphate,	Common, or tribasic phosphate of lime,	Tricalcium diphosphate,	Ca_32PO_4
	Subphosphate of lime,	Hydric calcic phosphate,	$HCaPO_4$
Soluble phosphate,	Bi-acid- or super- phosphate of lime,	Tetrahydric calcic diphosphate,	H_4Ca2PO_4
	Per-phosphate of iron,	Ferric phosphate,	$FePO_4$
	Protophosphate of iron,	Ferrous phosphate,	Fe_32PO_4
Microcosmic salt,	Ammonio-phosphate of soda,	Hydric sodic ammonic phosphate,	$HNa(NH_4)PO_4$
	Pyrophosphate, or bibasic phosphate of soda,	Sodic pyrophosphate,	$Na_4P_2O_7$
	Pyrophosphate of lime,	Calcic pyrophosphate,	$Ca_2P_2O_7$
	Meta- or mono- phosphate of soda,	Sodic metaphosphate,	$NaPO_3$
	Meta- or mono- phosphate of lime,	Calcic metaphosphate,	$Ca2PO_3$

Oxygen, sulphur, and other non-metals unite with the metals in more than one proportion. Those compounds which contain the larger proportion of the non-metal are named thus — mercur*ic* oxide, ferr*ic* (Lat. *ferrum*, iron) oxide; whilst the compounds containing the lower proportion of the non-metal are termed mercur*ous* oxide, or ferr*ous* oxide. There are acids which contain different amounts of oxygen united with the same metal or non-metal. Those richer in oxygen are termed phosphor*ic* or chlor*ic*; whilst the compounds which contain the lesser proportion of oxygen are called phosphor*ous* acid, or chlor*ous* acid. *Hypo**sulphurous acid means an acid poorer in oxygen than sulphurous acid; and *per*†-chloric acid is an acid containing more oxygen than is found in chloric acid. When such an acid as sulphuric unites with another substance, *ic* is changed into *ate*. Thus we have sodic sulph*ate*, and potassic phosph*ate*. Sulphur*ous* acid, nitr*ous* acid, &c., form sulph*ites*, nitr*ites*, &c. There are perchlorate, chlorate, chlorite, and hypochlorite of potassium, and other metals. Latin or Greek numerals are used to indicate the proportion of oxygen, or other non-metal in combination with a metal. Iron and oxygen united in the proportion of atom for atom may be termed protoxide or monoxide; higher atomic proportions of oxygen produce *di*, or *deut*oxides, *ter*, or *trit*oxides, *quad* or *tetr*oxides. We have a pentasulphide of calcium (Ca_2S_5), containing, as its name implies, five atoms of sulphur and two of calcium.

Bases, Acids, and Salts.—The term *base* is fre-

* Greek *hypo*, less. † Abbreviation of *hyper*, more.

quently met with in chemical writings. It is applied to those bodies which are converted into *salts* by the action of acids. There are four kinds of bases: 1st, Metallic oxides, such as lime; 2d, Compounds containing a metal, united with an atom of oxygen and an atom of hydrogen, such as sodic hydrate, or common caustic soda; 3d, Certain compounds, such as ammonia and trihydric phosphide; 4th, Many organic bodies containing nitrogen, such as strychnine or quinine. We have already seen that acids contain hydrogen. This hydrogen becomes replaced by a metal when the first class of bases is acted upon, and the oxygen of the metallic oxide and the hydrogen of the acid produce water. A similar reaction occurs when an acid acts upon a hydrate of a metal; but direct union takes place between acids and ammonia, and similar compounds and organic bases. A metal which, by union with oxygen, produces a base, is termed a *basyl.* Lime, or calcic oxide is a base, but the calcium is a basyl.

The portion of an acid which is capable of being separated from the hydrogen is termed an *oxion.* One atom of sulphur, four atoms of oxygen, and two of hydrogen enter into the composition of sulphuric acid. The sulphur and oxygen constitute *sulphion. Nitrion*, *carbion*, &c., are the *radicles*, or essential parts of nitric acid, carbonic acid, &c. These substances, however, have not been (nor are they likely to be) isolated.

It is usual to name compounds in harmony with the theory of their composition and constitution which happens to be present at the time. This practice

the atmosphere disappear together. The two gases have *combined chemically* with each other and formed water.

On the other hand, if a piece of wood, or a bit of straw, in which the elements are already chemically combined, be burned in the air, these elements are separated, and made to assume new states of combination, in which new states they escape into the air and become invisible. When a substance is thus changed, and converted or separated into other substances by the action of heat, or in any other way, it is said to be *decomposed.* If it more gradually decay and perish, as animal and vegetable substances do, by exposure to the air and moisture, it is said to undergo slow *decomposition.*

When, therefore, two or more substances unite together, so as to form a third, possessing properties different from both, they enter into chemical union—they form a *chemical combination* or chemical *compound.* And when, on the other hand, a compound body is so changed as to be converted into two or more substances different from itself, it is decomposed. Thus carbon, hydrogen, and oxygen undergo a chemical combination in the interior of the plant during the formation of wood; while wood, again, is decomposed, when in the retort of the vinegar-maker it is converted into charcoal, vinegar, and other substances.

Plants derive their food from both air and soil. The parts of plants which are not volatile must of course be derived from the soil; but the atmosphere contributes a large proportion of that portion of the

plants which is destructible by the agency of heat—carbon, oxygen, hydrogen, and nitrogen. These elements enter the plant partly by the minute pores of their roots, and partly by those which exist in the green parts of the leaf and of the young twig. The roots bring up food from the soil, the leaves take it in directly from the air.

Now, as the pores in the roots and leaves are very minute, carbon (charcoal) cannot enter them in a *solid* state; and as it does not dissolve in water, it cannot, in the state of simple carbon, be any part of the food of plants. The same is true of sulphur and phosphorus. Again, hydrogen gas neither exists in the air nor usually in the soil; so that, although hydrogen is always found in the substance of plants, it does not enter them in the state of gas. Oxygen, on the other hand, exists in the air, and *is* directly absorbed both by the leaves and by the roots of plants; while nitrogen, though it forms a large part of the atmosphere, does not enter *directly* into plants.

The whole of the carbon and hydrogen, therefore, and the greater part of the oxygen also, enter into plants in a state of *chemical combination* with other substances. The carbon is taken up chiefly in the state of carbonic acid, and of certain other soluble compounds which exist in the soil; the hydrogen and oxygen in the form of water; the nitrogen chiefly, in those of ammonia, or nitric acid. We shall conclude this chapter with the following table, which shows the atomic weights of the more important elements and their symbols. The Roman numerals placed after

each symbol indicate that it is a "monad" or "dyad," &c. The names in italics are those of non-metallic bodies; the rest are metals. The symbols are taken from the Latin names of the elements—hence Fe, from the Latin *ferrum*, stands for iron, and so on.

Name of element.	Symbol.	Atomic weight.	Name of element.	Symbol.	Atomic weight.
Aluminium,	Al^3	27.5	Iron,	Fe^4	56
Antimony,	Sb^5	122	Lead,	Pb^4	207
Arsenic,	As^5	75	Magnesium,	Mg^2	24
Barium,	Ba^2	137	Manganese,	Mn^7	55
Bismuth,	Bi^5	208	Mercury,	Hg^2	200
Boron,	B^3	11	Nickel,	Ni^4	58.8
Bromine,	Br^1	80	*Nitrogen*,	N^5	14
Cadmium,	Cd^2	112	*Oxygen*,	O^2	16
Calcium,	Ca^2	40	*Phosphorus*,	P^5	31
Carbon,	C^4	12	Platinum,	Pt^4	197.4
Chlorine,	Cl^1	35.5	Potassium,	K^1	39.1
Chromium,	Cr^6	52.5	*Silicon*,	Si^4	28
Cobalt,	Co^4	58.8	Silver,	Ag^1	108
Copper,	Cu^2	63.5	Sodium,	Na^1	23
Fluorine,	F^1	19	Strontium,	Sr^2	87.5
Gold,	Au^3	196.7	*Sulphur*,	S^6	32
Hydrogen,	H^1	1	Tin,	Sn^4	118
Iodine,	I^1	127	Zinc,	Zn^2	65

Sulphur is now generally regarded as dyad; cobalt, nickel, and iron as tetrads; arsenic and antimony as pentads; and manganese and chromium as hexads

CHAPTER III.

THE ELEMENTARY CONSTITUENTS OF PLANTS AND ANIMALS.

Although there are 64 elements, only a comparatively small number are found in animal and vegetable substances. Some of the elements have hitherto only been found in extremely minute quantities, and in but a few localities; and the most sagacious philosophers have been unable to discover any important functions which those rare elements discharge in the economy of nature. The following elements are always found in plants and animals, and appear to be absolutely essential to their existence: CARBON, HYDROGEN, OXYGEN, NITROGEN, PHOSPHORUS, SULPHUR, CHLORINE, POTASSIUM, CALCIUM, MAGNESIUM, and IRON. SODIUM is also necessary to animal life, but it is doubtful whether or not it is essential to plants. Traces of MANGANESE and FLUORINE are found in vegetables and animals, and are probably essential. SILICON does not occur in animals, but its oxide (silica, SiO_2) is abundant in the stems of the grasses, and it is often found in various kinds of plants. Nevertheless there are reasons for doubting the essentialness of silicon as an ingredient of plant-food. IODINE and BROMINE are found in marine or coast plants—rarely in those which grow in inland situations. Minute traces of the rare elements, LITHIUM, RUBIDIUM, and CÆSIUM, may be found frequently in

plants if skilfully sought for. COPPER, ZINC, LEAD, and TITANIUM, have all been detected in small quantities in plants; but there can be little doubt as to their presence being merely accidental. Copper is often found in animals, and especially in their livers. When we come to treat of Vegetable Nutrition, we shall revert to the subject, What are, and what are not, the essential constituents of plants?

Carbon (C).—When wood is burned in a covered heap, as is done by the charcoal-burners,—or is distilled in iron retorts, as in making wood-vinegar,—it is charred, and is converted into common wood-charcoal. This charcoal is the most usual and best-known variety of carbon. It is black, soils the fingers, and is more or less porous, according to the kind of wood from which it has been formed. Coke obtained by charring or distilling coal is another variety. It is generally denser or heavier than charcoal, though usually less pure. Black-lead is a third variety, still heavier and more or less impure. The diamond is the only form in which carbon occurs in nature in a state of perfect purity.

This latter fact, that the diamond is pure carbon—that it is essentially the same substance with the finest and purest lamp-black—is very remarkable; but it is only one of the numerous striking circumstances that every now and then present themselves before the inquiring chemist.

Charcoal, the diamond, lamp-black, and all the other forms of carbon, burn away more or less slowly when heated to redness in the air or in oxygen gas, and are converted into a kind of gas known by the

name of *carbonic dioxide.* The impure varieties, when burned, leave behind them a greater or less proportion of ash.

Sulphur (S) is a well-known solid substance of a light-yellow colour, and faint peculiar odour. It burns with a pale-blue flame, evolving fumes possessed of the strong, pungent, characteristic odour of burning matches. These fumes consist of sulphurous anhydride (SO_2). Sulphur fully oxidised, and united with hydrogen, forms Sulphuric acid.

Phosphorus (P) is a yellowish waxy substance of a peculiar odour, which smokes in the air, shines in the dark, takes fire by mere rubbing, and burns with a large bright flame and much white smoke. Like sulphur, it exists in all plants and animals, though in comparatively small quantity. Like sulphur, also, it is employed largely in the arts, especially in the manufacture of lucifer-matches. It combines in several proportions with oxygen, and forms, with hydrogen and oxygen, the important substance, phosphoric acid.

Hydrogen (H). — If sulphuric acid, mixed with twice its bulk of water, be poured upon iron-filings, or upon small pieces of zinc, the mixture will speedily begin to boil up, and bubbles of gas will rise to the surface of the liquid in great abundance. These are bubbles of hydrogen gas. The chemical changes which take place in this reaction are as follows: $H_2SO_4 + Zn = ZnSO_4 + 2H$.

If the experiment be performed in a bottle, the hydrogen which is produced will gradually drive out the atmospheric air it contained, and will itself take its

parts of potassic chlorate and one of black oxide of manganese.

A very elegant method of preparing the gas is to put a few grains of *red oxide of mercury* into a tube, and apply the heat of a lamp as in fig. 5. Oxygen gas will be given off while minute globules of metallic mercury will condense on the cool part of the tube. The presence of oxygen in the tube is shown by introducing into one end of it a half-kindled match, when it will be seen to burn up brilliantly.

Fig. 5.

It is the characteristic property of this gas, that a taper, when introduced into it, burns with great rapidity, and with exceeding brilliancy, and continues to burn till either the whole of the gas disappears or the taper is entirely consumed. In this respect it differs both from hydrogen and from common air. If a living animal is introduced into this gas, its circulation and its breathing become quicker—it is speedily thrown into a fever—it lives as fast as the taper burned—and after a few hours, dies from excitement and exhaustion. This gas is not lighter, as hydrogen is, but is about one-ninth part heavier, than common air.

In the atmosphere, oxygen exists in the state of gas. It forms about one-fifth of the bulk of the air we breathe, and is the substance which, in the air, supports and sustains the respiration of animals, and the combustion of burning bodies. It is necessary

also to the growth of plants, so that, were it by any cause suddenly removed from the atmosphere of our globe, every living thing would perish, and combustion would become impossible.

Nitrogen (N).—This gas is very easily prepared. Dissolve a little green copperas in water, and pour the solution into a flask, or crystal bottle, provided with a good cork. Add a little of the hartshorn of the shops (solution of ammonia) till it is quite muddy, put in the cork tight, and shake the bottle well for five minutes. Loosen the cork a little without removing it, so as to allow air to enter the bottle. Cork tight again and shake as before. Repeat this as often as the loosening of the cork appears to admit any air; and after finally shaking it, allow it to stand for a few minutes. The air now in the bottle is nearly pure nitrogen gas.* Or more simply, by placing a few pieces of phosphorus on a small dish, either floating on, or supported over, a plate containing a little water, igniting the phosphorus by means of a hot wire, and then placing over it a bell jar. The oxygen of the air in the jar is thus removed in combination with the phosphorus as phosphoric pentoxide, P_2O_5, which dissolves in the water, and leaves almost pure nitrogen.

If a lighted taper be introduced into the bottle, it will be extinguished by this gas, but no other effect will follow. The gas itself does not take fire as hydrogen does. Or if a living animal be introduced into it, breathing will instantly cease, and it will drop without signs of life.

* $FeSO_4 + 2(NH_4HO) = (NH_4)_2SO_4 + H_2O + FeO$; and $2FeO +$ O of air $= Fe_2O_3$.

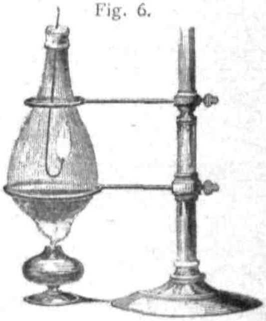
This gas possesses no other remarkable property. It is very little lighter than common air (as 97½ to 100), and exists in large quantity in an uncombined state in the atmosphere. Of the air we breathe it forms nearly four-fifths of the entire bulk—the remainder being chiefly oxygen. In the process above described for preparing the gas, the oxygen is absorbed by the iron, and the nitrogen left behind.

Oxygen, nitrogen, and hydrogen are incapable of being distinguished from common air, or from each other, by the ordinary senses; but by the aid of the taper they are readily recognised. Hydrogen extinguishes the taper, but itself takes fire; nitrogen simply extinguishes it; while in oxygen the taper burns rapidly and with extraordinary brilliancy.

Chlorine (Cl).—This is a greenish gas, about two and a half times heavier than atmospheric air. It cannot, even when largely mixed with air, be taken into the lungs without producing great irritation. It is soluble in its own volume of water, and its solution destroys organic colouring matters. It decomposes the offensive gases—sulphuretted hydrogen, and phosphoretted hydrogen, and also putrescent vegetable and animal matters. It is largely used as a bleaching agent and a purifier of air. It is readily obtained by pouring muriatic acid (spirits of salt) upon the black oxide of manganese of the shops, contained in a flask, and applying a gentle heat ($MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2$), as in the annexed figure. If the flask be of colourless glass, the colour of the gas will immediately become perceptible, and its odour will diffuse itself through the room. A burning taper plunged into it burns with a dull red smoky flame.

In combination with the metallic bases of potash, soda, lime, and magnesia, it forms the *chlorides* of potassium, sodium (common salt), calcium, and magnesium; and in one or other of these states it generally enters into the roots of plants, and exists in their ash.

Fig. 6.



Iodine (I) is a solid substance of a grey colour and metallic lustre, very much resembling filings of lead. It has a peculiar odour, not unlike that of chlorine, an acrid taste, and stains the fingers of a brown colour. It is distinguished by two properties — by being changed into a beautiful violet vapour when heated, and by giving with starch a beautiful blue compound. It occurs in small quantities in sea-water, and in marine and many fresh-water plants.

Bromine (Br) is a dark brownish-red heavy liquid, possessed of a strong odour, giving a yellowish-red vapour, and colouring starch yellow. It exists in sea-water, in certain salt springs, and has been detected in the ashes of certain plants. It probably accompanies chlorine and iodine into all plants, though the proportion, which is still less than that of iodine, has hitherto prevented its presence from being detected.

As *chlorine* forms *chlorides*, so *iodine* forms *iodides*, and *bromine* forms *bromides*, with the metals already mentioned.

Fluorine (F) is a very corrosive gas, of which little

is yet known. It exists in small quantity in the teeth and bones, and in the blood and milk, of animals. Traces of it also have been detected in the ashes of some plants; so that it is probably necessary to the growth of both animals and vegetables. With metals, it forms *fluorides;* and fluoride of calcium, or fluorspar, is the best-known and most common of its combinations. Fluorine is never found uncombined.

Potassium, or Kalium (K).—This metal is lighter than water, its specific gravity being only 865—water being 1000. It is always found in combination with other elements, chiefly with oxygen and carbonic acid (K_2CO_3), chlorine (KCl), and iodine (KI). It instantly rusts on exposure to air, decomposes water with such energy that the hydrogen which it displaces takes fire and is reconverted into water. The metal is preserved under naphtha, which is composed of carbon and hydrogen.

Sodium (Symbol Na, from natrium, another name of the metal).—A metal resembling potassium, but of heavier specific gravity—970. Like potassium, it is obtained by heating to a very high temperature a mixture of charcoal and sodic carbonate ($Na_2CO_3 + C = Na_2 + 2CO$). Sodium occurs in enormous quantity in certain mines and in sea-water, as sodic chloride ($NaCl$). Sodium also occurs in the form of carbonate (Na_2CO_3) in kelp.

Calcium (Ca).—This metal is never met with except as a scientific curiosity.[a] It is prepared with great difficulty by the action of sodium upon calcic chloride = $CaCl_2 + Na_2 = Ca + 2NaCl$. Combined with oxygen, it constitutes lime; with oxygen and carbon, limestone, chalk, marble, and a great variety

of minerals, such as stalactite, calc-spar, &c. Gypsum and alabaster are compounds of calcium, oxygen, and sulphur. In spring and other waters calcium often occurs as calcic chloride and sulphate.

Magnesium (Mg).—A white metal, specific gravity 1.7. It is prepared by decomposing its chloride by sodium. It burns evolving an exceedingly brilliant white light, and forms its only compound with oxygen —*magnesia*. The rock termed dolomite is a compound of a mixture of magnesic and calcic carbonates. Chloride, iodide, and bromide of magnesium are present in many mineral waters; and the well-known *Epsom* salts consist of magnesic sulphate. The bitter flavour of the water of the Dead Sea is chiefly due to the large proportion of magnesic chloride which it contains. In the mineral termed kainit, used as a manure, magnesic chloride ($MgCl_2$) is largely present.

Iron (Fe, from the Latin *ferrum*).—This most valuable of the metals is found chiefly in the form of oxide, carbonate, and sulphide. Sulphur-stone, or iron pyrites is FeS_2. Sulphide of iron is found in many rocks, soils, and metallic ores. Of oxides there are three: protoxide, or ferrous oxide (FeO); sesqui, per, or ferric oxide (Fe_2O_3); and protosesqui, magnetic, or ferroso-ferric oxide (Fe_3O_4).

Proportions of the Elements in Plants.—Of the one solid substance, carbon, and the three gases, hydrogen, oxygen, and nitrogen, above described, the organic part of all vegetable and animal bodies is essentially made up. In those organic substances which contain nitrogen, sulphur and phosphorus also are present, but generally in minute proportion.

But the organic part of plants contains these four substances in very different proportions. Thus, of all the vegetable productions which are gathered as food by man or beast, in their *dry state*, the

Carbon forms nearly *one-half* by weight;
Oxygen rather more than *one-third;*
Hydrogen little more than 5 *per cent;*
Nitrogen from ½ to 4 *per cent;*
Sulphur 1 to 5 *per cent;*
Phosphorus about a *thousandth part.*

This is shown in part by the following table, which exhibits the actual composition of 1000 lb. of some varieties of the more common crops, when made *perfectly dry*:—

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.
Hay, . .	458 lb.	50 lb.	387 lb.	15 lb.	90 lb.
Red clover hay,	474	50	378	21	77
Potatoes, . .	440	58	447	15	40
Wheat, . .	461	58	434	23	24
Wheat-straw, .	484	53	389⅓	3⅓	70
Oats, . .	507	64	367	22	40
Oat-straw, .	501	54	390	4	51

It is to be observed, however, that in drying by a gentle heat, 1000 lb. of common hay from the stack lost 158 lb. of water; of clover hay, 210 lb.; of potatoes wiped dry externally, 759 lb.; of white turnips, 900 lb.; of wheat, 145 lb.; of wheat-straw, 260 lb.; of oats, 151 lb.; and of oat-straw, 287 lb. But the quantity of water depends altogether on the state of the specimens examined, hence analyses vary. 1000 lb. of young grass contain 700 to 800 lb. of water: the same when thoroughly air-dry (as hay).

about 140 lb. Straw contains about the same amount. The above table represents their composition when made perfectly dry.

The bodies of animals contain also a large proportion of water; but the dry matter of their bodies, as a whole, is distinguished from that of plants, by containing a larger proportion of nitrogen, sulphur, and phosphorus. Some parts of the bodies of animals are particularly rich in these ingredients. Thus—

Dry *lean muscle* contains 12 to 14 per cent of *nitrogen;*
Dry *hair* or *wool* about 5 per cent of sulphur; and
Dry *bone* about 12 per cent of phosphorus.

But in animals, as in plants, the chief constituents are carbon and oxygen. Thus, lean beef, blood, white of egg, and the curd of milk, when quite dry, consist in 100 parts of about—

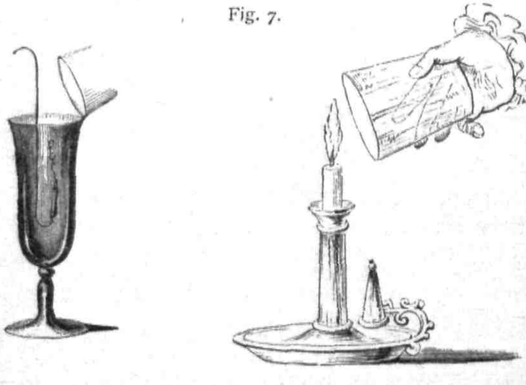
	Per cent.
Carbon,	55
Hydrogen,	7
Nitrogen,	16
Oxygen, with a little sulphur and phosphorus,	22
	100

We shall now consider the proportion of some of the compounds used as food by plants, and from which their volatile portion is obtained.

Carbonic Acid (H_2CO_3).—If a few pieces of chalk or limestone, $CaCO_3$, or of common soda, be put into the bottom of a tumbler, and a little spirit of salt or muriatic acid (HCl), dissolved in water, be poured upon them, a boiling up, or *effervescence,* will take place, and a gas will be given off, which will

gradually collect and fill the tumbler; and when produced very rapidly, may even be seen to run over its edges. This gas is carbonic dioxide.* It cannot be distinguished from common air by the eye; but if a lighted taper be plunged into it (fig. 7), the flame will immediately be extinguished, while the gas will remain unchanged. This kind of air is so heavy, that it may be poured from one vessel into another, and its presence in the second vessel recognised as before by the use of the taper. Or it may be poured upon a lighted candle which it will instantly extinguish (fig. 7). This gas has also a peculiar odour, and is ex-

Fig. 7.



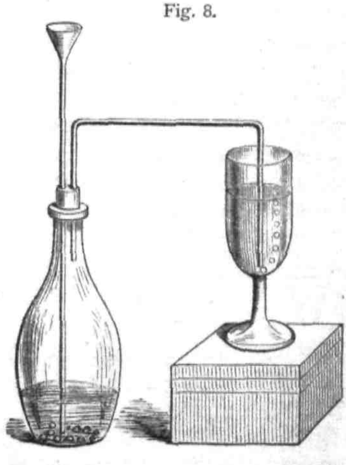
ceedingly suffocating, so that if a living animal be introduced into it, life immediately ceases. It is absorbed by water—a pint of water absorbing, or dis-

* $CaCO_3 + 2HCl = CaCl_2 + H_2CO_3$; and $H_2CO_3 = H_2O + CO_2$. The compound commonly called carbonic acid is carbonic dioxide (CO_2). Real carbonic acid would have the composition given above, H_2CO_3.

solving a pint of the gas, and acquiring a faintly acid taste.

This gas derives its name of acid from this taste, which it imparts to water, and from its property of reddening vegetable blue colours, and of combining with alkaline* substances to form *carbonates*. The former property may be shown by passing a stream of the gas through a decoction of red cabbage — as in fig. 8—when the liquid will gradually become red;

Fig. 8.



the latter, by putting lime-water into the glass instead of the decoction of red cabbage, when the stream of gas will render it milky, forming *carbonate of lime.*

Carbonic dioxide exists in the atmosphere; it is given off from the lungs of all living animals while

* *Acids* are bodies containing hydrogen, which hydrogen can be replaced partly or entirely by metals. They have generally a sour taste like vinegar, and redden vegetable blues. Alkalies, again, have a peculiar taste called *alkaline*, of which the flavour of common soda or of hartshorn are examples; they restore the colour to vegetable blues which have been reddened by an acid, and they unite with acids to form chemical combinations, known by the name of salts or saline combinations.

and through the soil, and rarely reaches the roots of plants in a pure state. So waters that rise up in springs are rarely pure. They always contain earthy and saline substances in solution, and these they carry with them when they are sucked in by the roots of plants.

It has been above stated, that water absorbs (dissolves) its own bulk of carbonic acid; it dissolves, also, smaller quantities of the oxygen and nitrogen of the atmosphere; and hence, when it meets any of these gases in the soil, it becomes impregnated with them, and conveys them into the plant, there to serve as a portion of its food.

In nature, water never occurs in a pure state. It generally contains both gaseous and saline substances in a state of solution; and this, no doubt, is a wise provision, by which the food of plants is constantly renewed and brought within their reach.

2. Water, as we have shown above, is composed of oxygen and hydrogen, and by certain chemical processes it can readily be resolved, or decomposed *artificially*, into these two gases. The same thing takes place *naturally* in the interior of the living plant. The roots and leaves absorb the water; but if in any part of the plant hydrogen be required for the formation of the substance which it is the function of that part to produce, a portion of the water of the sap is decomposed either directly or indirectly, and its hydrogen worked up; while its oxygen is set free, or converted to some other use. So, also, where oxygen is required, and cannot be obtained from some more ready source, water is decomposed, the oxygen made use of, and the hydrogen liberated Water,

therefore, which abounds in the vessels of all growing plants, if not directly converted into the substance of the plant, is yet a ready and ample source from which a supply of either of the elements of which it consists may at any time be obtained.

It is a beautiful adaptation of the properties of this all-pervading compound—water—that its elements should be so fixedly bound together as rarely to separate in external nature, and yet to be thus at the command and easy disposal of the vital powers of the humblest order of living plants.

Ammonia (NH_3).—If the sal-ammoniac $(NH_4)Cl$, or the ammonic sulphate $(NH_4)_2SO_4$, of the shops, be mixed with quicklime, a powerful odour is immediately perceived, and an invisible gas is given off,* which strongly affects the eyes. This gas is ammonia (NH_3). Water dissolves, or absorbs it in very large quantity, and this solution of the gas in water forms the common hartshorn of the shops. The white solid smelling-salts of the shops (carbonate of ammonium) are a compound of ammonia with carbonic acid.

Ammonia consists of nitrogen and hydrogen only, in the proportion of 14 parts of the former to 3 parts of the latter by weight; or 17 lb. of ammonia contain 14 lb. of nitrogen and 3 lb. of hydrogen.

The decay of animal substances is an important natural source of this compound. During the putrefaction of dead animal bodies, ammonia is invariably given off. From the animal substances of the farm-yard it is evolved during their decay or putrefaction, as well as from all solid and liquid manures of animal origin.

* $CaO + 2(NH_4)Cl = CaCl_2 + H_2O + 2NH_3$.

Ammonia is naturally formed, also, during the decay of vegetable substances in the soil. This happens in one or other of three ways.

a. As in animal bodies, by the direct union of the nitrogen with a portion of the hydrogen of which they consist.

b. Or by the combination of a portion of the hydrogen of the decaying plants with the nitrogen of the air.

c. Or when they decompose in contact, at the same time, with both air and water—by their taking the oxygen of a quantity of the water, and disposing its hydrogen at the moment of liberation to combine with the nitrogen of the air, and form ammonia.

The production of ammonia by either of the two latter modes takes place most abundantly where the oxygen of the air does not gain very ready access. Such are open subsoils, in which vegetable matter abounds. And thus one of the benefits which follow from thorough draining and subsoil-ploughing is, that the roots penetrate and fill the subsoil with vegetable matter, which, by its decay in the confined atmosphere of the subsoil, gives rise to this production of ammonia. When thus formed in the soil, it is at once absorbed and retained by the humic or ulmic acid (yet to be described), until it enters into the roots of living plants.

Ammonia is also formed naturally during the chemical changes that are produced in volcanic countries, through the agency of subterranean fires. It escapes often in considerable quantities from the hot lavas, and from crevices in the heated rocks.

It is produced artificially by the distillation of ani-

mal substances (hoofs, horns, &c.), and during the burning, coking, and distillation of coal. Indeed the great source of ammonia is now the liquor from the gas-works, which, after being neutralised with hydrochloric acid or sulphuric acid, furnishes the sal-ammoniac, or the "sulphate of ammonia," of commerce. Soot contains much ammonia.

Of the ammonia which is given off during the putrefaction of animal and vegetable substances, a variable proportion rises into the air, and floats in the atmosphere, till it is either decomposed by natural causes, or is dissolved and washed down by the rains. In the latter case it sinks into the ground, and finds its way into the roots of plants. In our climate, cultivated plants appear to derive a considerable proportion of their nitrogen from ammonia. It is one of the most valuable fertilising substances contained in farmyard manure; and as it is usually present in greater proportion in the liquid than in the solid contents of the farmyard, much real wealth is lost, and the means of raising increased crops thrown away, in the quantities of liquid manure which are almost everywhere permitted to run waste.

Nitric Acid (HNO_3) is a powerfully corrosive liquid, known in the shops by the familiar name of *aquafortis*. It is prepared by pouring oil of vitriol (sulphuric acid) upon saltpetre, and distilling the mixture $H_2SO_4 + KNO_3 = KHSO_4 + HNO_3$. The aquafortis of the shops is a mixture of the pure acid with water.

Pure nitric pentoxide (N_2O_5) consists of nitrogen and oxygen only, united in the proportions of 14 parts of nitrogen, by weight, to 40 of oxygen. Mixed

rapidity. The small proportion of carbònic acid in the atmosphere affords an important part of their food to plants, and the watery vapour aids in keeping the surfaces of animals and plants in a moist and pliant state; while, in due season, it descends also in refreshing showers, or studs the evening leaf with sparkling dew.

There is thus in the composition of the atmosphere a beautiful adjustment to the nature and necessities of living beings. The energy of the pure oxygen is tempered, yet not too much weakened, by the admixture of nitrogen gas. The carbonic acid, which, when undiluted, is noxious, especially to animal life, is mixed with the other gases in so minute a proportion as to be harmless to animals, while it is still beneficial to plants; and when the air is overloaded with watery vapour, it is provided that it shall descend in rain.

But the air contains, besides, many other substances not essential to its composition, but which exercise, nevertheless, an important influence both upon animal and vegetable life. We have already seen that nitric acid, and probably ammonia, are produced in it by the agency of electricity, and are brought down by the rains. There are continually rising into it, also, vapours and exhalations of various kinds from the earth's surface. The sea sends up a portion of its common salt and other constituents, and the land the numberless forms of volatile matter which arise from decaying animal and vegetable substances, from festering marshes, from burning volcanoes, and from countless manufactories and chemical operations. As the ocean receives all that water can carry into it,

so the atmosphere receives everything that the air can bear up.

And lest these ever-rising exhalations should contaminate the air, and render it unfit for the breathing of animals, the rains, as they descend, dissolve, wash out, and bring them back again to the soil. Thus they purify at once the atmosphere through which they fall, and bear refreshment to the land, and the means of fertility, wherever they come.

CHAPTER IV.

THE CONSTITUENTS OF THE ASHES OF PLANTS.

That portion of animal or vegetable substance which remains after combustion is termed *ash.* Its proportion varies from a mere trace to 10 or 12 per cent. The following substances are found in the ashes of plants, either as such or in combination :—

Sulphuric Acid (H_2SO_4)—known also as oil of vitriol—is a very heavy, oily-looking, sour, and corrosive liquid, which becomes hot when mixed with water, chars and blackens straw or wood when immersed in it, and is capable of dissolving many organic and inorganic substances. It is manufactured by burning sulphur, and leading the sulphurous vapours into large leaden chambers, in which they are mixed with nitrous fumes, steam, and air. It consists of sulphur and oxygen only--combined with

water. One pound of sulphur produces about three pounds of the strongest sulphuric acid.

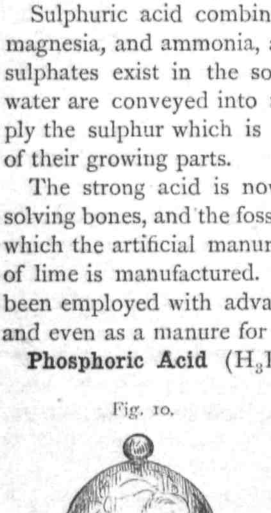
There is a compound termed sulphuric anhydride, composed of oxygen and sulphur (SO_3). When it is dissolved in water it produces sulphuric acid, or oil of vitriol—$SO_3 + H_2O = H_2SO_4$.

Sulphuric acid combines with potash, soda, lime, magnesia, and ammonia, and forms *sulphates*. These sulphates exist in the soil, and when dissolved by water are conveyed into the sap of plants, and supply the sulphur which is necessary for the formation of their growing parts.

The strong acid is now employed largely for dissolving bones, and the fossil "phosphate of lime" from which the artificial manure known as *super-phosphate* of lime is manufactured. In a diluted state it has been employed with advantage as a steep for barley, and even as a manure for turnips.

Phosphoric Acid (H_3PO_4).—If a piece of phosphorus be kindled in the air, it burns with a brilliant flame, and gives off dense white fumes. These white fumes are phosphoric pentoxide (P_2O_5). They are produced by the union of the burning phosphorus with the oxygen of the atmosphere. 100 lb. of phosphorus, when burned, form 229½ lb. of phosphoric pentoxide. If the experiment be performed under a glass, as in the annexed figure, the white fumes will

Fig. 10.



condense on the cool inside of the vessel in the form of a white powder, which speedily absorbs moisture from the air, and runs to a liquid. When phosphorus burns freely in air it forms P_2O_5. This, when combined with water (H_2O), forms phosphoric acid, thus—

$$P_2O_5 + 3\ H_2O = 2\ (H_3PO_4.)$$

This acid is very sour and corrosive. It combines with potash, lime, &c., and forms *phosphates*, and in these states of combination it exists in soils and manures, and enters into plants. The bones of animals contain a large proportion of this acid, in combination with lime and magnesia.

The composition on the ends of lucifer-matches consists chiefly of phosphorus mixed with potassic chlorate and sulphur. In the patent safety-matches the phosphorus is on the box, the other ingredients on the matches.

Silicic Anhydride (SiO_2).—This compound (sometimes termed silica) is the dioxide of the non-metal *silicon*. It is the most abundant constituent of the crust of the globe, existing in nearly every kind of rock. It is found in the form of six-sided crystals in the mineral termed *rock-crystal*, and in several forms of *quartz*. Opal is silica in the uncrystallised form, and *calcedony* and *agate* are mixtures of crystallised and uncrystallised silica. The common *flint* is a variety of calcedony, and carnelian and amethyst are silica coloured with oxide of iron. Melted with potash, soda, alumina, oxide of iron, &c., silica forms the various kinds of glasses, some of which, containing large proportions of soda or potash, are soluble in water Compounds of silica are termed

potassium compound. Mixed with water it forms caustic soda (sodic hydrate, HNaO), a body very like caustic potash, but not so energetic in its reactions. It is prepared in the same way as potassic hydrate, and is largely used in the manufacture of soap and other industrial products.

Sodic Chloride (NaCl).—The metal sodium, and the gaseous, non-metallic element chlorine, unite readily, and produce common salt, or chloride of sodium. Sea-water contains 2.7 per cent of sodic chloride, or at the rate of rather more than ¼ lb. per imperial gallon. Immense beds of common salt have been discovered in India, the United States, Hungary, Poland, Spain, in the north of England, and in the north of Ireland. *Rock-salt* is crystallised sodic chloride. Common salt has an agreeable flavour if used in moderate quantity. It forms cubes soluble in three parts of cold water and in nearly the same proportion of hot water—a rather curious fact. Strong alcohol does not dissolve it. At a bright red heat it fuses, and at a white heat, sufficiently prolonged, it volatilises.

Lithia (Li_2O) and lithic hydrate resemble potassic oxide and hydrate. Only minute quantities of lithium have, as yet, been detected in plants.

Rubidia and Cæsia are two compounds which have a remarkable resemblance to potash. They have been found,* but only in very minute quantities, in various plants.

Calcic Oxide or Lime (CaO).—Pure lime is a white infusible powder. When mixed with water it evolves

* Occurrence of Rubidia, Cæsia, and Lithia in Plants—C. A. Cameron in Journal of Royal Dublin Society, 1867.

heat, and forms calcic hydrate or slaked lime ($CaO + H_2O = CaH_2O_2$). Lime is soluble in 700 parts of cold water, but it requires a much larger proportion of hot water to dissolve it, and alcohol has no effect upon it. When lime in masses is exposed to the air, it absorbs water. It gradually slakes and crumbles into a fine powder. Fifty-six parts of lime combine with eighteen parts of water, and yet the resulting compound is quite dry. Lime is called an alkaline earth because, like the alkalies potash and soda, it restores reddened litmus to its blue colour. It possesses considerable causticity. It acts upon organic matter in the same way that potash does, but not with anything like the same energy.

Calcic Carbonate ($CaCO_3$) occurs in a very pure form in the minerals *Iceland spar* (rhombohedrons), *aragonite* (six-sided prisms), and white marble (in small granular crystals). It is found abundantly in many plants, in the bones of animals, and in the shells of crustaceans, &c. In close vessels it may be fused, but heated in the open air it gives off carbonic dioxide, and leaves lime ($CaCO_3 = CaO + CO_2$).

Magnesic Oxide or Magnesia (MgO) is formed by heating magnesic carbonate to redness ($MgCO_3 = MgO + CO_2$). Magnesia is a bulky white powder, which forms a hydrate (MgH_2O_2), but requires many thousand times its weight of water to dissolve it. It is tasteless, odourless, and infusible. Moistened and placed on turmeric paper, it changes the colour of the latter from yellow to brown; hence it is said to be alkaline. Magnesia carbonate is found as a white hard mineral, termed magnesite. It occurs associated with calcic carbonate in many minerals, rocks, and

all soils. Lime and magnesia are always found in the ashes of plants, combined with phosphoric, carbonic, and silicic acids. In the plants they may exist combined with sulphuric acid and organic acids. It is not often that the earths are found uncombined in the ashes of plants.

Oxides of Iron.—Ferric oxide (Fe_2O_3) is always found in small quantity in the ash of plants. It is a reddish-brown substance, well known as rust of iron. It is generally found combined with water ($Fe_2O_3 + 3H_2O$).

Ferrous Oxide (FeO) may exist in plants, but during their combustion it would, if present, be converted into ferric oxide by absorption of oxygen.

Oxides of Manganese.—There are several oxides of the metal manganese, and one of them, manganoso-manganic oxide (Mn_3O_4), is found in the ashes of plants, though in the living vegetable manganese probably exists in some other form. Manganoso-manganic oxide is a red substance. It is formed by highly heating with access of air any of the other oxides.

CHAPTER V.

STRUCTURE AND MODES OF GROWTH OF THE PLANT.

The Structure of Plants.—From the compound substances described in the preceding chapters, plants derive the various elements found in their ashes, and

the carbon, hydrogen, oxygen, nitrogen, the sulphur and phosphorus of which their organic part consists. The living plant possesses the power of absorbing these compound bodies, of *decomposing* them in the interior of its several vessels, and of *re-compounding* their elements in a different way, so as to produce new substances—the ordinary products of vegetable life. Let us consider the wonderful mechanism in which these operations are conducted.

A perfect plant consists of three several parts: a root, which throws out arms and fibres in all directions into the soil; a trunk, which branches into the atmosphere on every side; and leaves, which, from the ends of the branches and twigs, spread out a more or less extended surface into the surrounding air. Each of these parts has a peculiar structure, and special functions are assigned to it.

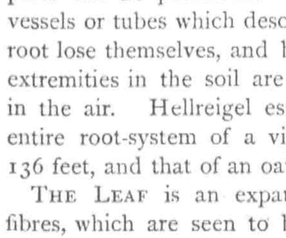
THE STEM of any of our common trees consists of three parts—the pith in the centre, the wood surrounding the pith, and the bark which covers the whole. The pith consists of a collection of minute cells, supposed to communicate horizontally with the external air through the medullary rays and the outer bark; while the wood and inner bark are composed of long tubes bound together in a *vertical* position, so as to be capable of carrying liquids up and down between the roots and the leaves. When a piece of wood is sawn across, the ends of these tubes may be distinctly seen. The branch is only a prolongation of the stem, and has a similar structure.

THE ROOT, immediately on leaving the trunk or stem, has also a similar structure. But as the root tapers away, the pith disappears,—in some, as in the

walnut and horse-chestnut, gradually—in others immediately. The bark also thins out, and the wood softens, till the white tendrils, of which its extremities are composed, consist only of a colourless spongy mass, full of pores, and in which no distinction of parts can be perceived. In this spongy mass the vessels or tubes which descend through the stem and root lose themselves, and by these tubes the spongy extremities in the soil are connected with the leaves in the air. Hellreigel estimates the length of the entire root-system of a vigorous barley-plant to be 136 feet, and that of an oat-plant to be 155 feet.

THE LEAF is an expansion of the twig. The fibres, which are seen to branch out from the base through the interior of the leaf, are prolongations of the vessels of the wood, and are connected with similar prolongations of the inner bark, which usually lie beneath them. The green exterior portion of the leaf is, in like manner, a continuation of the outer or cellular tissue of the bark, in a very thin and porous form. The pores, or mouths (*stomata*), contained in the green part, are an essential feature in the structure of the leaves, and are very numerous. The leaf of the common lilac contains as many as 120,000 of them on a square inch of surface. They are generally most numerous on the under part of the leaf; but in the case of leaves which float upon water, they are chiefly confined to the upper part.

Fig. 11.



The annexed woodcut shows the appearance of the oval pores (*p*) on the leaf of the garden balsam. Connected with these pores, the green part of the leaf consists of or contains a collection of tubes or vessels which stretch along the surface of the leaf, and communicate, as we have said, with those of the inner bark.

Each of these principal parts of the plant performs peculiar functions.

FUNCTIONS OF THE ROOT.—The root serves to fix the plant firmly in the soil, and to keep it in an erect position. It is also the organ by which a large proportion of the food of the plant is collected and absorbed. In the case of many plants, the root is a storehouse or magazine, filled with nourishment either for the use of the plant or for that of its offspring. In autumn the farmer removes the roots of the crops—turnips, mangels, &c.—which by cultivation had attained to a large size. Allowed to remain in the soil for a second year they would become exhausted by supplying nourishment to the flowers and seeds of the second year's growth. The root sends out fibres in every direction through the soil in search, as it were, of water and of *liquid* food, which its extremities suck in and send forward with the sap to the upper parts of the tree. The part of the roots where absorption chiefly takes place is near the extremities, but it has been shown that the tops of the roots or spongioles take no part in the process. It is to aid the roots in procuring the food more rapidly that in the art of culture such substances are mixed with the soil as experience has shown to be favourable to the growth of the plants we wish to raise.

The chemical changes which the food is made to undergo in entering or passing along the roots are not yet understood.

Nearly all the plants cultivated by the farmer have roots which are adapted to existence in the soil. Many plants, however (some of which are cultivated by the gardener), have air-roots—that is, roots which are altogether out of the soil, and are capable of directly absorbing nutriment from the atmosphere. Indian corn frequently throws out roots from the lower portion of its stem, and although they usually descend into the soil, yet that portion which is above ground acts like a true air-root. The roots of aquatic plants have no outer skin or integument such as land plants have when they are removed from the soil. There are, however, plants, such as rice, which can grow in either soil or water.

FUNCTIONS OF THE LEAF.—It is not so obvious to the common observer that the leaves spread out their broad surfaces into the air for the same purpose precisely as that for which the roots diffuse their fibres through the soil; the only difference is, that while the roots suck in chiefly *liquid*, the leaves inhale almost solely *gaseous* food. In the daytime, whether in the sunshine or in the shade, the green leaves are continually absorbing carbonic acid from the air, and giving off oxygen gas—that is to say, they are continually appropriating carbon from the air. When night comes, this process is reversed, and they begin to absorb oxygen and to give off carbonic acid. But the latter process does not go on so rapidly as the former; so that, on the whole, plants, when growing, gain a large portion of carbon from the air. The

actual quantity, however, varies with the season, with the climate, and with the kind of plant. The proportion of its carbon, which has been derived from the air, is greatly modified, also, by the quality of the soil in which the plant grows, and by the comparative abundance of liquid food which happens to be within reach of its roots. It has been ascertained, however, that in our climate, on an average, not less than from one-third to four-fifths of the entire quantity of carbon contained in the crops we reap from land of average fertility is really obtained from the air.

We see then why, in arctic climates, where the sun, once risen, never sets again during the entire summer, vegetation should almost rush up from the frozen soil; the green leaf is ever gaining from the air and never losing, ever taking in and never giving off carbonic acid, since no darkness ever interrupts or suspends its labours.

How beautiful, too, does not the contrivance of the expanded leaf appear! The air contains only one gallon of carbonic acid in 2500, and this proportion has been adjusted to the health and comfort of animals to whom this gas is hurtful. But to catch this minute quantity, the tree hangs out thousands of square feet of leaf—in perpetual motion, through an ever-moving air; and thus, by the conjoined labours of millions of pores, the substance of whole forests of solid wood is slowly extracted from the fleeting winds. We have already mentioned the number of pores which have been observed on a square inch of leaf; and when we add that on a single oak-tree seven millions of leaves have been counted, the multitude of absorbing mouths in a forest—like those of

the coralline animals in a reef—will appear equal to the most gigantic effects.

The green stem of the young shoot, and the green stalks of the grasses, also abound in pores, and consequently absorb carbonic acid, and give off oxygen, as the green leaf does; and thus a larger supply of food is afforded when the growth is most rapid, or when the short life of the annual plant demands much nourishment within a limited time. The yellow and red leaves and parts of plants give off no oxygen, but, on the contrary, carbonic acid. Another great function of the leaves is the exhalation of watery vapour; and to such an extent does this take place, that it has been calculated that from a single acre in crop, from three to five million pounds of water are exhaled during the growth of the crop.

FUNCTIONS OF THE STEM.—From the root the sap ascends through the vessels of the woody stem till it is diffused over the interior of the leaf by the woody fibres which the leaf contains. During this passage the substances which the sap contains undergo certain chemical changes, which are as yet not well understood. From the woody fibre of the leaf—along the vessels which lie beneath these fibres, and are covered by the green part of the leaf—and after it has absorbed or given off the gases which the pores transmit, the sap is returned towards the outer part of the stem, and through the vessels of the *inner* bark descends again to the root.

In the plant, till it has passed maturity, most of the vessels are full of sap, and this sap is in continual motion upwards within the stem, and downwards along its surface within the inner bark. In spring

and autumn the motion is more rapid. In winter it is sometimes scarcely perceptible; yet the sap, except when frozen, is supposed to be rarely quite stationary in any part of the tree.

The Vegetable Cell.—All the structures of a plant are found to be composed of minute bags, or vesicles termed cells, lying closely together. To the organised bodies cells are what molecules are to mineral compounds. The smallest portion of water which can exist is a molecule—the most minute structure in the composition of a plant is its cell. As the molecule is formed out of the indivisible atoms, so the cell is produced from the most elementary principle found in living beings, namely, *protoplasm*, or *formative matter*. This substance is mucilaginous, and sometimes granular. It fills up the interior of the cells, and there is no doubt but that it furnishes the materials from which new cells are formed. It exhibits no trace of organised structure, and it is believed to be the most simple principle in animals and plants—that from which all the other structures are developed.

The primary cell of the vegetable is globular, but various circumstances contribute to modify its shape, which varies in different plants and in different parts of the same vegetable. In the pith of rushes it is star-shaped, and in loose tissue it is generally an irregular spheroid. In cotton and flax the cells are long and slender. The size of the cell is very variable: in the spores of fungi they are only the 1-5000th part of an inch in diameter; whilst the marine plant, *Caulerpa prolifera*, consists of a single cell often a foot in length. In general, however, cells are very small.

The wall of the vegetable cell is elastic and permeable to liquids and gases, but in old cells these properties exist in a diminished degree. The wall consists chiefly of the substance termed cellulose (which will be described in the next chapter). The more important contents of the cell comprise protoplasm, coloured particles (chlorophyll corpuscles), and starch. There are also present sugar, saline compounds, oily matters, &c. By the aid of the microscope we can detect in cells one or more round or lenticular-shaped bodies, transparent, colourless, or yellowish: these are termed nuclei (singular, nucleus). They are filled with a yellowish mucilaginous fluid, in which are contained excessively minute rounded bodies, termed *nucleoli* (singular, *nucleolus*). The nucleus is not an immature cell, and there is some reason to suppose that it is mainly composed of fat. Although the nucleus never becomes a new cell, it is concerned in the production of one. For this purpose the nucleus sometimes divides itself into two parts, and the protoplasm forms a cell-wall round each moiety. Cells multiply by division. In some plants the growth of cells proceeds with a wonderful degree of rapidity—as, for example, in the case of a species of puff-ball, which is stated to produce three or four hundred millions per hour.

Cellular Tissue.—The *parenchyma*, or *cellular tissue* of vegetables, consists altogether of ordinary cells, and contains no vessels. Some of the lower kinds of plants (*cellulares*), such as sea-weeds, are composed exclusively of parenchyma.

Woody Tissue is composed of long and slender cells, tapering at each extremity. These cells overlap

each other, forming what is termed woody *fibre*. *Bast* tissue is a modification of woody tissue, but the cells are longer and more elastic. This tissue is abundant in flax, and is also present in the *bast* or inner bark of trees. Hemp, &c. (but not cotton), consists chiefly of bast tissue.

Vascular Tissue consists of tubes produced by the complete coalition of several simple cells and of wood-cells. It is usually found in bundles. These tubes assume a great variety of shapes. *Spiral* vessels are very long tubes clustered together, and having each a spiral fibre or fibres in its interior.

Pitted Vessels, or dotted ducts, are common in plants. They contain numerous pores, which are conspicuous in the wood of the cane or rattan when cut across.

Lactiferous Vessels consist of branched tubes filled with a milk-like liquid. They are abundant on the under side of leaves, and within the inner bark, but are not found in other parts of the plant. The sap ascends through the pitted vessels. Some vegetable physiologists class dotted ducts with cellular tissue.

CHAPTER VI.

OXIMATE CONSTITUENTS OF PLANTS

lant various chemical compounds exist, y all be included in three main groups or classes—nitrogenous, non-nitrogenous (including the saccharine and pectose groups), and fatty.

When the grain of wheat, barley, oats, rye, Indian corn, &c., is sent to the mill to be ground, two products are obtained—the bran or husk, and the flour. When washed free from flour, the bran or husk is tasteless, insoluble in water, and woody. It is the same thing, indeed, for the most part, as the cellular and fibrous part of wood or straw.

Again, when a portion of the flour is made into dough, and this dough is kneaded with the hand under a stream of water upon a piece of muslin, or on a fine sieve, as long as the water passes through milky—there will remain on the sieve a glutinous sticky substance resembling bird-lime, while the milky water will gradually deposit a pure white powder. This white powder is *starch*, the adhesive substance which remains on the sieve is *gluten*. Both of these substances exist, therefore, in the flour; they both also exist in the grain.

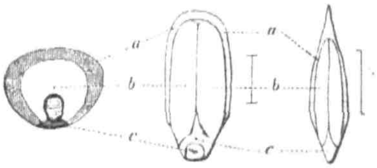
Fig. 12.

Further, when bruised wheat, oats, Indian corn, linseed, or even chopped hay and straw, are boiled in alcohol or ether, a portion of oil or fat, of wax and of resin, is extracted, and is obtained separately by allowing the solution to evaporate to dryness in the air.

Thus, from the seed or grain we have obtained four different substances—the woody part which covers it, starch, gluten, and fat. The annexed woodcut shows

the position and relative quantities of the last three substances in the seeds of wheat, barley, and Indian corn. Thus *a* shows the position of the oil in the outer part of the seed. It exists in minute drops, enclosed in six-sided cells, which consist chiefly of gluten.

Fig. 13.



b the position and comparative quantity of the starch, which in the heart of the seed is mixed with only a small proportion of gluten. *c* the germ or chit, which contains much gluten.

These substances represent the three great classes of organic bodies of which the bulk of all plants is made up.

The woody matter and the starch represent what is called the *carbo-hydrate* group. The oil or resin represents the *fatty* group. The gluten represents the *gluten*, or albumin group.

We shall briefly describe these several groups or classes of substances.

Carbo-hydrates comprehend a great number of different substances, possessing different properties, but all characterised by this similarity in composition, that they contain either six or its multiples of atoms of carbon, combined with hydrogen and oxygen in the proportions in which the latter elements exist in water. They are consequently termed carbo-hydrates, or hydrates of carbon, though their hydrogen

and oxygen do not actually exist as water. If oil of vitriol be poured upon a saturated solution of sugar contained in a long narrow glass vessel or tube, the mixture will blacken, solidify, and swell up to five or six times its volume. The acid takes away the hydrogen and oxygen (which become water), and the residue is carbon, or charcoal.

Composition of the principal carbo-hydrates :—

Sucrose— (Cane-sugar) $C_{12}H_{22}O_{11}$.	Amidin— (Starch) $xC_6H_{10}O_5$.
Lactose— (Milk-sugar) $C_{12}H_{22}O_{11}2H_2O$.	Dextrin, $C_6H_{10}O_5$. Inulin, $C_6H_{10}O_5$. Glycogen, $C_6H_{10}O_5$.
Lævulose— (Fruit-sugar) $C_6H_{12}O_6$.	Arabin, $2(C_6H_{10}O_5)H_2O$. Bassorin, $xC_6H_{10}O_5$.
Dextrose— (Starch-sugar) $C_6H_{12}O_6H_2O$.	Cellulin— (Cellulose) $3(C_6H_{10}O_5)$.

The *saccharine*, or sugar group, comprise about a dozen substances more or less closely allied to common, or cane sugar.

Cane-sugar (*Sucrose*) occurs abundantly in the sugar-cane, the maple, beetroot, carrots, and a great variety of vegetables. In the form of sugar candy, it occurs in large four-sided oblique rhomboidal prisms; but loaf-sugar is made up of very minute transparent crystals. It dissolves in one-third of its weight of cold water, but it is very sparingly soluble in alcohol, and is insoluble in ether.

Glucose is a term which includes several kinds of sugar, closely resembling each other, but differing a little in their constitution, as shown by their action upon polarised light.

Grape-sugar is a variety of glucose, and crystallises

with difficulty in little hard cubes; soluble in about their own weight of water, and in about five times their weight of boiling alcohol. In sweetening power, 2½ parts of grape-sugar are only equal to one of cane-sugar; but their nutritive properties appear to be equal. Sulphuric acid, which decomposes cane-sugar, unites chemically with grape-sugar.

Dextrose is a kind of glucose prepared by digesting starch or woody fibre (linen rags, &c.) in diluted sulphuric acid. In this process, 1 molecule of starch forms with 4 molecules of water 2 molecules of dextrose. The acid remains unchanged. In the process of germination, and in that of *malting* seeds, starch is converted into a variety of glucose. Cane-sugar, when boiled in acid solutions, is converted partly into dextrose, partly into lævulose, or fruit-sugar.

Fruit-sugar (*Lævulose*, or *inverted* sugar) is found associated with other kinds of sugar in treacle, honey, and fruits (cherries, plums, strawberries, &c.), when ripe and acidulous. It is probably a mixture of two sugars; for though not crystallisable itself, it gradually splits up into a crystallisable sugar and a syrup, from which no crystals are obtainable. Lævulose dissolves in alcohol.

Lactose (*Lactin*) is the saccharine substance found in milk. It is soluble in about six parts of water, but does not dissolve in alcohol or ether. Its crystals are small and hard. Whilst cane and grape sugars readily ferment, milk-sugar does not ferment, though milk itself does. It possesses very little sweetening power.

Starch (*Fecula*, or *Amylum*) is widely distributed

throughout the vegetable kingdom, and is the most abundant constituent of vegetable food. There are several varieties of it. It occurs in oval or rounded granules formed of layers. The granules of rice-starch do not exceed 1-3000th of an inch in diameter; whilst those of the *Canna*, or *tous les mois*, are about 1-200th of an inch in diameter. Starch is one and a half times as heavy as water, in which liquid and in alcohol it is insoluble. Water at 140° Fahr. breaks up the granules, and a portion of it (*amidin*) dissolves. With iodine, starch forms a rich violet-coloured compound. Heated to 401° Fahr., it is converted, without change of composition, into a soluble substance—*dextrin*, or "British gum."

Dextrin, or something very like it, is supposed to exist in the sap of plants.

Cellulin (*Cellulose*) is a white, flavourless substance, insoluble in water, alcohol, and ether. It constitutes the bulk of wood and of the cellular tissue of vegetables. Cotton, white paper, linen, and the pith of the elder, are nearly pure cellulin. Woody fibre consists chiefly of cellulin, but it is also in part composed of a much harder substance—*lignin*, which was long considered a mere modification of cellulose. In lignin, the hydrogen exists in greater quantity than is necessary to form water.

Gums are found in almost every kind of plant, but are more abundant in some than in others.

Arabin is a compound of arabic, or gummic acid ($C_{12}H_{22}O_{11}$), with calcium and potassium. It is well known under the name of *gum-arabic*—a substance which exudes from several species of acacia. Gummic acid is soluble in water, when precipitated by

muriatic acid from solution of gum-arabic ; but when dried it does not again dissolve, but merely forms, with water, a jelly. In this state it is *metagummic acid.*

Cerasin, or cherry-tree gum, is chiefly arabic acid united with calcium.

Bassorin (*Mucilage*) is a kind of gum, insoluble in water, with which, however, it swells up into a gelatinous mass. It is abundant in linseed, quince seed, and in many roots. Gum-tragacanth contains it in large proportion. It is highly probable that the gums are digestible.

Glycogen is a sugar-producing substance found in the liver. Nearly 10 per cent of the (dry) weight of the oyster consists of this substance.

Inulin is a variety of starch, found in the dandelion, chicory, and some other plants. With iodine it strikes a *yellow* colour.

Pectose Bodies.—In most fruits and roots there is a substance which causes their juices to gelatinise. It is termed *vegetable jelly*. The bulk of vegetable jelly is supposed to be a substance termed *pectose.* The composition of this body is unknown, because it cannot be separated from the cellulose of the roots and fruits without changing its nature. It is insoluble in water, alcohol, and ether. By the action of acids or ferments pectose is converted into *pectin,* which is soluble in water. Pectin is capable of being thrown into a state of fermentation by the action of *pectase* (said to be present in the juices of plants), and converted into *pectic* and *pectosic* acids. These acids are naturally formed in fruits and roots. Long-continued boiling (in water) of vegetable jelly produces *parapectic* acid. Treated with alkalies, *parapectic acid*

c. Fibrinogen resembles the preceding, and is found in animal fluids produced by disease.

d. Vitellin is a granular substance found in the yolk of eggs.

3. *Derived albumins.*—These dissolve in diluted solutions of acids and alkalies and in solution of common salt, but not in water. They comprise *casein* or alkali-albumin, and *syntonin* or acid-albumin (from muscle).

4. *Fibrin.*—This proteid is insoluble in water, and is with difficulty dissolved by acids and alkalies. It is elastic. It is the substance which chiefly constitutes the *clot* of blood, and it is largely present in muscle. According to Liebig it is found in the *gluten* of plants. Fibrin varies in its properties according to the sources from which it is derived.

5. *Coagulated albumin.*—This is the substance thrown down from soluble albumin by heat or acids. It is insoluble in water and not readily dissolved by strong acids and alkalies.

6. *Amyloid*, or *Lardacein.*—A product of diseased action in the liver and elsewhere. Though its name implies that it is "like starch," it is a true proteid.

7. All proteids, except amyloid, are converted by the action of the gastric juice into *peptones.* These are very soluble in water, and are not coagulated by acids or alkalies. The composition of proteids is not with certainty known. The following are the composition of some of them as given by chemists of reputation:—

	Carbon.	Hydrogen.	Oxygen.	Nitrogen	Sulphur
Fibrin, . .	52.6	7.9	21.8	17.4	1.2
Albumin, . .	51.27	7.13	22.12	16.24	2.12
Vegetable casein.	53.9	7.2	23	15	0.9
Animal casein, .	53.6	7.2	22.6	15.7	1

In washing the dough of wheaten flour, a portion remains on the sieve or muslin, to which the name of gluten is given. This substance contains nitrogen in addition to the carbon, hydrogen, and oxygen which are present in the bodies described in the preceding sections, and is the representative of an entire class of important substances into which nitrogen enters as a constituent. We shall briefly mention the most important of these substances.

1°. *Gluten.*—This is obtained from the dough of wheaten flour, in the way already described. It is insoluble in water, partly soluble in alcohol, which extracts from it a fatty oil, and entirely and easily soluble in vinegar (acetic acid), or in solutions of caustic potash or soda. Besides the fatty oil which it contains, the crude gluten, as it is washed from wheaten flour, consists of at least two substances—one soluble in alcohol (*glutin*), the other insoluble in this liquid (gluten), and which appears closely to resemble *coagulated albumin.* When moist, gluten is nearly colourless, and is tenacious and adhesive like bird-lime ; but when perfectly dry it is hard, brittle, and of a grey or brownish colour.

2°. *Albumin.*—The white part of eggs is called albumin by chemists. In the natural state it is a glairy thick liquid, which can be diffused through or dissolved in water, but which coagulates, or becomes solid and opaque, when heated to about 180° Fahrenheit, or nearly to the temperature of boiling water. In this coagulated state it is insoluble in water or in alcohol, but dissolves in vinegar, or in solutions of caustic potash or soda. When dried it becomes hard, brittle, semi-transparent, and of a brownish colour.

When the expressed juice or sap of plants is heated, a solid substance coagulates, and separates from it in opaque white flocks. This substance possesses nearly all the properties of the albumin of the egg, and is therefore called vegetable albumin.

Albumin exists in plants not only in the liquid state, as in the sap of plants, but also in the coagulated state. In the husks and envelopes of many seeds—the bran of corn, for example—and in the solid parts of woody and herbaceous plants, it is found in this state in greater or less proportion.

3°. *Casein.*—When rennet, vinegar, or diluted muriatic acid is added to milk, it coagulates or curdles, and a white curd separates from the whey. Alcohol or ether extracts the fat or butter from the coagulated mass, and leaves pure curd behind. To this curd chemists give the name of casein.

When cold water is shaken up with oatmeal for half an hour, and is then allowed to subside, the clear liquid becomes troubled on the addition of a little acid, and a white powder falls, possessing nearly all the properties of the casein of milk.

The sap of nearly all plants—the expressed juice of the potato, the turnip, and other roots, after being heated to coagulate the albumin—and the solution obtained when the meal of the bean, the pea, and other legumes, is treated with warm water—yield, on the addition of an acid, precipitates of this substance differing but little from one another.

Vegetable casein, therefore, is a constant constituent of our best-known and cultivated plants. To the variety obtained from the oat the name of *avenin* has

been given; and to that yielded by the bean, the pea, and the vetch the name of *legumin*.

The proteid richest in nitrogen is *gliadin*. It has recently been found in gluten. It contains 18.01 per cent of nitrogen.

Gelatin is a nitrogenous substance found in animals (in the bones), but not in vegetables. *Chondrin* resembles gelatin, and is the chief ingredient of cartilages. Both contain more nitrogen and less carbon and sulphur than are found in albuminoids. Isinglass, glue, and size are forms of gelatin. Gelatin swells and softens in cold water and dissolves in hot water.

Many active principles (quinine, strychnine, &c.)—various acids, such as tartaric, oxalic, &c.—and different saline substances, exist in plants; but the study of these compounds is beyond the scope of this work.

CHAPTER VII.

THE COMPOSITION OF SOILS.

The term SOIL is given to the upper stratum of the crust of the earth, which is specially adapted for the maintenance of plants. Geologically, soil is a species of "rock," though usually it is a loosely coherent substance very unlike the dense masses popularly termed rocks.

Soils consist of two parts; of an *organic* part,

which can readily be burned away when the soil is heated to redness; and of an *inorganic* part, which is fixed in the fire, and which consists entirely of earthy and saline substances.

The Organic Part of Soils is derived from the remains of vegetables and animals which have lived and died in or upon the soil, which have been spread over it by winds, rivers, and rains, or which have been added by the hands of man for the purpose of increasing its natural fertility.

This organic part varies very much in quantity in different soils. In some, as in peaty soils, it forms from 50 to 70 per cent of their whole weight; and even in rich long-cultivated soils it has been found, in a few rare cases, to amount to as much as 25 per cent. In general, however, it is present in much smaller proportion, even in our best arable lands. Oats and rye will grow upon a soil containing only 1½ per cent, barley when 2 to 3 per cent are present, while good wheat soils generally contain from 4 to 8 per cent. The rich alluvial soil of the valley of the Nile contains only 5 per cent of dry organic matter. In stiff and very clayey soils, 10 to 12 per cent is sometimes found. In very old pasture-lands, and in gardens, vegetable matter occasionally accumulates so as to overload the upper soil. The comparative value of peaty or boggy soils may be judged of from the fact, that of the 5000 flowering-plants of Central Europe, only 300 grow on peaty or boggy soils, and these mostly belong to the *rush* and *sedge* families, useless to the farmer.

The organic matter in the soil is chiefly composed of a brown or black substance, to which the name of

humus has been given by some writers. Mulder considers it to be a mixture of three substances, —namely, compounds of water, or of water and ammonia, with *geic acid* ($C_{20}H_{12}O_7$),* *humic acid* ($C_{20}H_{12}O_6$),† and *ulmic acid* ($C_{20}H_{14}O_6$).‡ In addition to these bodies, Berzelius has pointed out two others, *crenic* acid (from the Greek *krene*, a spring) and *apocrenic* acid. There is some doubt as to their composition. All these compounds retain ammonia with great tenacity—a property of great utility in connection with the supply of ammonia to plants, as we shall see further on.

Another influence of the organic portion of the soil, whether naturally formed in it or added to it as manure, is not to be neglected. It contains—as all vegetable substances do—a considerable quantity of inorganic, that is, of saline and earthy matter, which is liberated as the organic part decays. Thus living plants derive from the remains of former races, buried beneath the surface, a portion of that inorganic food which can only be obtained from the soil, and which, if not thus directly supplied, must be sought for by the slow extension of their roots through a greater depth and breadth of the earth in which they grow. The addition of manure to the soil, therefore, places within the easy reach of the roots not only organic but also inorganic food.

The Inorganic Part of Soils is that which remains when everything combustible is burned away by combustion in the open air. It consists of two

* From the Greek *ge*, the earth.

† From the Latin *humus*, the ground.

‡ From the Latin *ulmus*, an elm.

portions, one of which is *soluble* in water, the other *insoluble.*

1. *The saline or soluble portion.*—In this country, the surface-soil of our fields, in general, contains very little soluble matter. If a quantity of soil be dried in an oven, a pound weight of it taken, and a pint and a half of pure boiling rain-water poured over it, and the whole well stirred and allowed to settle, the clear liquid, when poured off and boiled to dryness, may leave from 30 to 100 grains of mineral mixed with a variable quantity of organic matter. This matter will consist of common salt, gypsum, sodic sulphate (Glauber's salts), magnesic sulphate (Epsom salts), with traces of the chlorides of calcium, magnesium, and potassium, and of potash, soda, lime, and magnesia, in combination with nitric and phosphoric, and with the humic and other organic, acids. It is from these soluble substances that the plants derive the greater portion of the saline ingredients contained in the ash which they leave when burned.

Nor must the quantity thus obtained from the soil be considered too small to yield the whole supply which a crop requires. A single grain of saline matter in every pound of a soil a foot deep, is equal to 500 lb. in an acre. This is more than is carried off from the soil in ten rotations (forty years), where only the wheat and barley are sent to market, and the straw and green crops are regularly, and without loss, returned to the land in the manure.

In some countries—indeed, in some districts of our own country—the quantity of saline matter in the soil is so great as in hot seasons to form a white

incrustation on the surface. This may often be seen in the neighbourhood of Durham; and is more especially to be looked for in districts where the subsoil is sandy and porous, and more or less full of water. In hot weather, the evaporation on the surface causes the water to ascend from the porous subsoil; and as this water always brings with it a quantity of saline matter, which it leaves behind when it rises in vapour, it is evident that, the longer the dry weather and consequent evaporation from the surface continue, the thicker the incrustations will be, or the greater the accumulations of saline matter on the surface. Hence, where such a moist and porous subsoil exists in countries rarely visited by rain, as in the plains of Peru, of Egypt, or of India, the country is whitened over in the dry season with an unbroken snowy covering of the different saline substances above mentioned.

When rain falls, the saline matter is dissolved, and descends again to the subsoil. In dry weather it re-ascends. Hence the *surface-soil* of any field will contain a larger proportion of soluble inorganic matter in the middle of a hot dry season than in one of even ordinary rain. Hence, also, the fine dry weather which, in early summer, hastens the growth of corn, and later in the season favours its ripening, does so probably, among its other modes of action, by bringing up to the roots from beneath a more ready supply of those saline compounds which the crop requires for its healthful growth. In some countries, however, this saline matter ascends in such quantity as to render the soil unfit to grow the more tender crops. Thus, on the plains of Attica, when the rainy season

ends, saline substances begin to rise to the surface in such abundance as by degrees entirely to burn up or prevent the growth of grass, though abundant wheat crops are yearly ripened.

2. *The insoluble portion* (usually about 95 per cent) of the soil is composed of silica, aluminic silicates, calcic and magnesic carbonates, and phosphates, oxides of iron, and traces of a few other compounds. *Clays* are nearly altogether composed of silica and alumina. The latter substance is only found—probably as the result of accident—in the club-mosses, and we have not described it when treating of the ash-ingredients of plants. It is the only oxide of the metal aluminium (Al_2O_3). It occurs nearly in a pure state in the mineral *corundum*; and, tinged with oxide of chromium, in the *ruby* and *sapphire*; and, coloured with iron and manganese oxides, in *emery*. Chemically prepared, it occurs as a white powder, insoluble in water, but uniting greedily with that liquid to form $Al_2O_3 + 3H_2O$. White porcelain consists of aluminic silicate, free from potash, soda, and iron. Pipe-clay and blue clay are silicates of aluminium. The common *clay* of soils is essentially aluminic silicate mixed with organic matter, alkalies, oxide of iron, &c. The most frequent silicate in clay is as follows—$Al_2O_3 + 2SiO_2 + 2H_2O$.

Pure clay, when moist, forms a stiff, tenacious substance, insoluble in water, and capable of being moulded into any shape. It has a peculiar and well-known odour. Clay, like alumina, absorbs water, ammonia, and organic substances.

a. If an ounce of soil be intimately mixed with a pint of water till it is perfectly softened and diffused

through it, and if, after shaking, the heavy parts be allowed to settle for a few minutes, the sand will subside, while the clay—which is in finer particles, and is less heavy—will still remain floating. If the water and fine floating clay be now poured into another vessel, and be allowed to stand till the water has become clear, the sandy part of the soil will be found on the bottom of the first vessel, and the clayey part on that of the second, and they may be dried, and weighed separately.

b. If 100 grains of dry soil, not peaty or unusually rich in vegetable matter, leave no more than 10 of clay when treated in this manner, it is called a *sandy soil;* if from 10 to 40, a *sandy loam;* if from 40 to 70, a *loamy soil;* if from 70 to 85, a *clay loam;* from 85 to 95, a *strong clay soil;* and when no sand is separated at all by this process, it is a pure *agricultural clay.*

c. This pure clay contains silica and alumina, in the proportion of about 60 of the former to 40 of the latter. Soils of pure clay rarely occur—it being well known to all practical men that the strong clays (tile-clays), which contain from 5 to 15 per cent of sand, are brought into arable cultivation with the greatest possible difficulty. It will rarely, almost never, happen, therefore, that arable land will contain more than 30 to 35 per cent of alumina.

d. If a soil contain more than 5 per cent of carbonate of lime, it is called a *marl;* if more than 20 per cent, it is a *calcareous* soil. *Peaty soils,* of course, are those in which the vegetable matter predominates very much.

The Diversities of Soils and Subsoils.— *Varie-*

ties of Soil.—Though the substances of which soils *chiefly* consist are so few in number, yet every practical man knows how very diversified they are in character —how very different in agricultural value. Thus, in some of the southern counties of Scotland, we have a white soil, consisting apparently of nothing else but chalk; in the centre of England, a wide plain of dark-red land; in the border counties of Wales, and on many of our coal-fields, tracts of country almost perfectly black; while yellow, white, and brown sands and clays give the prevailing character to the soils of other districts. Such differences as these arise from the different proportions in which the sand, lime, clay, and the oxide of iron and organic matter which colour the soils, have been mixed together.

But how have they been so mixed—differently in different parts of the country? By what natural agency? For what end?

Subsoil.—Again, the surface-soil rests on what is usually denominated the *subsoil.* This also is very variable in its character and quality. Sometimes it is a porous sand or gravel, through which water readily ascends from beneath, or sinks in from above; sometimes it is light and loamy, like the soil that rests upon it; sometimes stiff, and more or less impervious to water.

The most ignorant farmer knows how much the value of a piece of land depends upon the character of the surface-soil,—the intelligent improver understands best the importance of a favourable subsoil. "When I came to look at this farm," said an excellent agriculturist, "it was spring, and damp, growing

weather: the grass was beautifully green, the clover shooting up strong and healthy, and the whole farm had the appearance of being very good land. Had I come in June, when the heat had drunk up nearly all the moisture which the *sandy subsoil* had left in the surface, I should not have offered so much rent for it by ten shillings an acre." He might have said also, "Had I taken a spade, and dug down 18 inches in various parts of the farm, I should have known what to expect in seasons of drought."

But how come subsoils thus to differ—one from the other—and from the surface-soil that rests upon them? Are there any principles by which such differences can be accounted for—by which they can be foreseen—by the aid of which we can tell what kind of soil may be expected in this or that district, even without visiting the spot, and on what kind of subsoil it is likely to rest?

Geology explains the cause of many of these differences, and supplies us with principles by which we can predict the general quality of both soils and subsoils in the several parts of entire kingdoms; and where the soil is of inferior quality, and yet susceptible of improvement, the same principles indicate whether the means of improving it are likely to exist in any given locality, or to be attainable at a reasonable cost.

It will be proper shortly to illustrate these direct relations of geology to agriculture.

CHAPTER VIII.

ORIGIN AND CLASSIFICATION OF SOILS.

Geology is that branch of knowledge which embodies all ascertained facts in regard to the nature and internal structure, both physical and chemical, of the solid parts of our globe. This science has many close relations with practical agriculture. It especially throws much light on the nature and origin of soils—on the causes of their diversity—on the agricultural capabilities, absolute and comparative, of different farming districts and countries—on the unlike effects produced by the same manure on different soils—on the kind of materials, by admixture with which they may be permanently improved—and on the sources from which these materials may be derived.

It tells beforehand, also, and by a mere inspection of the map, what is the general character of the land in this or that district of a country—where good land is to be expected—where improvements are likely to be effected—of what kind of improvements this or that district will be susceptible—and where the intending purchaser may hope to lay out his money to the greatest advantage.

Decay of Rocks.—If we dig down through the soil and subsoil to a sufficient depth, we always come sooner or later to the solid rock. In many places the rock actually reaches the surface, or rises in cliffs, hills, or ridges, far above it. The surface (or crust) of our globe, therefore, consists everywhere of a more or less

solid mass of rock, overlaid by a covering, generally thin, of loose materials. The upper or outer part of these loose materials forms the soil.

The geologist has travelled over great part of the earth's surface, has examined the nature of the rocks which everywhere repose beneath the soil, and has found them to be very unlike in appearance, in hardness, and in composition—in different countries and districts. In some places he has met with a sandstone, in other places a limestone, in others a slate or hardened rock of clay. But a careful comparison of all the kinds of rock he has observed has led him to the general conclusion that they are all either sandstones, limestones, or clays of different degrees of hardness, or a mixture in different proportions of two or more of these kinds of matter.

When the loose covering of earth is removed from the surface of any of these rocks, and this surface is left exposed, summer and winter, to the action of the winds and rains and frosts, it may be seen gradually to crumble away. Such is the case even with many of those which, on account of their greater hardness, are employed as building-stones, and which, in the walls of houses, are kept generally dry; how much more with such as are less hard, or lie beneath a covering of moist earth, and are continually exposed to the action of water? The natural crumbling of a naked rock thus gradually covers it with loose materials, in which seeds fix themselves and vegetate, and which eventually form a soil. The soil thus produced partakes necessarily of the chemical character and composition of the rock on which it rests, and to the crumbling of which it owes its origin. If the rock be

a sandstone, the soil is sandy—if a claystone, it is a more or less stiff clay—if a limestone, it is more or less calcareous—and if the rock consists of any peculiar mixture of those three substances, a similar mixture is observed in the earthy matter into which it has crumbled.

Led by this observation, the geologist, after comparing the rocks of different countries with one another, compared next the soils of various districts with the rocks on which they immediately rest. The *general* result of this comparison has been, that in almost every country the soils, as a whole, have a resemblance to the rocks beneath them, similar to that which the loose earth derived from the crumbling of a rock before our eyes bears to the rock of which it lately formed a part. The conclusion, therefore, is irresistible, that soils, generally speaking, have been formed by the crumbling or decay of the solid rocks—that there was a time when these rocks were naked and without any covering of loose materials—and that the accumulation of soil has been the slow result of the natural degradation or wearing away of the solid crust of the globe.

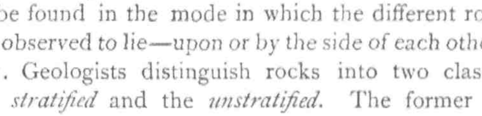
Causes of Diversity of Soils.—The cause of the diversity of soils in different districts, therefore, is no longer obscure. If the subjacent rocks in two localities differ, the soils met with there are likely to differ also, and in an equal degree.

But why, it may be asked, do we find the soil in some countries uniform in mineral character—that is, containing the same general proportions of sand, clay, lime, &c., or coloured red by similar quantities of oxide of iron—and general fertility over hundreds or

thousands of square miles, while in others it varies from field to field—the same farm often presenting many well-marked differences both in mineral character and in agricultural value? A chief cause of this is to be found in the mode in which the different rocks are observed to lie—upon or by the side of each other.*

1. Geologists distinguish rocks into two classes, the *stratified* and the *unstratified.* The former are found lying over each other in separate beds or *strata*, like the leaves of a book when laid on its side, or like the layers of stones in the wall of a building. The latter—the unstratified rocks—form hills, mountains, or sometimes ridges of mountains, consisting of one more or less solid mass of the same material, in which no layers or strata are usually anywhere or distinctly perceptible. Thus, in the following diagram (fig. 14), A and B represent *unstratified* masses, in connection with a series of *stratified* deposits, 1 2 3, lying over

Fig. 14.



each other in a horizontal position. On A one kind of soil will be formed, on C another, on B a third, and on D a fourth—the rocks being all different from each other.

If from A to D be a wide valley of many miles in extent, the undulating plain at the bottom of the valley, resting in great part on the same rock (2), will be covered by a similar soil. On B the soil will be different for a short space; and again it will differ at

* For another important cause, see Chapter X.

the bottom of the valley C, and on the first ascent to A, at both of which places the rock (3) rises to the surface. In this case the stratified rocks lie horizontally; and it is the undulating nature of the country which, bringing different kinds of rock to the surface, causes a necessary diversity of soil.

2. But the degree of *inclination* which the beds possess is a more frequent cause of variation in the character of the soil in the same district, and even at very short distances. This is shown in the annexed diagram (fig. 15), where A B C D E represent

Fig. 15.

the mode in which the stratified rocks of a district of country not unfrequently occur in connection with each other.

Proceeding from E in the plain, the soil would change when we came upon the rock D, but would continue pretty uniform in quality till we reached the layer C. Each of these layers may stretch over a comparatively level tract of perhaps hundreds of miles in extent. Again, on climbing the hillside, another soil would present itself, which would not change till we arrived at B. Then, however, we begin to walk over the edges of a series of beds, and the soil may vary with every new *stratum* or bed we pass over, till we gain the ascent to A, where the beds are much thinner, and where, therefore, still more frequent variations may present themselves.

Everywhere over the British Islands, valleys are

hollowed out, as in the former of these diagrams (fig. 14), by which the different rocks beneath are in different places exposed and differences of soil produced; or the beds are more or less inclined, as in the latter diagram (fig. 15), causing still more frequent variations of the land to appear. By a reference to these facts, therefore, many of the *greater* diversities which the soils of the country present may be satisfactorily accounted for.

Uniformity in Composition and Arrangement of Stratified Rocks.—A fact, alike important to agriculture and to geology, is the natural order or mode of arrangement in which the stratified rocks are observed to occur in the crust of the globe. Thus, if 1 2 3 (fig. 14) represent three different kinds of rock,—a limestone, for example, a sandstone, and a hard clay rock (a shale or slate), lying over each other in the order here represented,—then, in whatever part of the country—nay, in whatever part of the world these same rocks are met with, they will always be found in the same position. *The bed 2 or 3 will never be observed to lie over the bed* 1.

This fact is important to geology, because it enables this science to arrange all the stratified rocks in a certain invariable order—which order indicates their relative age or antiquity—since that rock which is lowest, like the lowest layer of stones in the wall of a building, must generally have been the first deposited, or must be the oldest. It also enables the geologist, on observing the kind of rock which forms the surface in any country, to predict at once whether certain other rocks are likely to be met with in that country or not Thus at C (fig. 14), where the

rock 3 comes to the surface, he knows it would be in vain, either by sinking or otherwise, to seek for the rock 1, the natural place of which is far above it; while at D, he knows that by sinking he is likely to find either 2 or 3, if it be worth his while to seek for them.

To the agriculturist this fact is important, among other reasons,—

1. Because it enables him to predict whether certain kinds of rock, which may be used with advantage in improving his soil, are likely to be met with within a reasonable distance or at an accessible depth. Thus, if the bed D (fig. 15) be a limestone, the instructed farmer at E knows that it is not to be found by sinking into his own land, and therefore brings it from D; while to the farmer upon C it may be less expensive to dig down to the bed D in one of his own fields, than to cart it from a distant spot, where it occurs on the surface. Or, if the farmer requires clay, or marl, or sand, to ameliorate his soil, this knowledge of the constant relative position of beds enables him to say where these materials are to be got, or where they are to be looked for, and whether the advantage to be derived is likely to repay the cost of procuring them.

2. It is observed that, when the soil on the surface of each of a series of rocks, such as C or D

or less unfruitful limestone soil; yet at either extremity of the tract D, where the soil is made up of

an admixture of the decayed portions of the two adjacent rocks, the land may be of average fertility —the sand of C may adapt the adjacent clay to the growth of turnips, while the lime of E may cause it to yield large returns of wheat.* Thus, to the tenant in looking out for a farm, or to the capitalist in seeking an eligible investment, a knowledge of the mutual relations of geology and agriculture will often prove of the greatest assistance. But how little is such really useful knowledge diffused among either class of men—how little have either tenants or proprietors been hitherto guided by it in their choice of the localities in which they desire to live!

3. The further fact that the several stratified rocks are remarkably constant in their general mineral character, renders this knowledge of the order of relative superposition still more valuable to the agriculturist. Thousands of different beds are known to geologists to occur on various parts of the earth's surface, each occupying its own unvarying place in the series. Most of these beds also, when they crumble or are worn down, produce soils possessed of some peculiarity by which their general agricultural capabilities are more or less affected,—and these peculiarities may *generally* be observed in soils formed from rocks of the same age—that is, occupying the same place in the series—in whatever part of the world we find them. Hence, if the agricultural geologist be informed that his friend has bought, or is in treaty for a farm or an estate, and that it is situated upon such and such a rock or geological formation, or is in the immediate neighbourhood of such another,—he can immediately give

* See pp. 98, 99

a very probable opinion in regard to the agricultural value of the soil, whether the property be in England, in Australia, or in New Zealand. If he knows the nature of the climate, also, he will be able to estimate with tolerable correctness how far the soil is likely to repay the labours of the practical farmer—nay, even whether it is likely to suit better for arable land or for pasture; and if for arable, what species of grain and root crops it may be expected to produce most abundantly.

These facts are so very curious, and illustrate so beautifully the value of geological knowledge—if not to A and B, the holders and proprietors of this and that small farm, yet to enlightened agriculturists, to scientific agriculture in general—that I shall explain this part of the subject more fully in a separate section. To those who are now embarking in such numbers in quest of new homes in our numerous colonies—who hope to find, if not a more willing, at least a more attainable, soil in new countries—no kind of agricultural knowledge can at the outset,—I may say, even through life,—be so valuable as that to which the rudiments of geology will lead them. Those who prepare themselves the best for becoming farmers or proprietors in Canada, in New Zealand, or in wide Australia, leave their native land in general without a particle of that preliminary practical knowledge which would qualify them to say, when they reach the land of their adoption, "on this spot rather than on that—in this district rather than that—will I purchase my allotment, because, though both appear equally inviting, yet I know, from the geological structure of the country, that here I shall have

the more permanently productive soil; here I am more within reach of the means of agricultural improvement; here, in addition to the riches of the surface, my descendants may hope to derive the means of wealth from mineral riches beneath." And this oversight has arisen chiefly from the value of such knowledge not being understood—often from the very nature of it being unknown, even to otherwise well-instructed practical men. It is not to men well skilled merely in the details of local farming, and who are therefore deservedly considered as authorities, and good teachers in regard to local or district practice, that we are to look for an exposition, often not even for a correct appreciation, of those general principles on which a universal system of agriculture must be based—without which, indeed, it must ever remain a mere collection of empirical rules, to be studied and laboriously mastered in every new district we go to—as the traveller in foreign lands must acquire a new language every successive frontier he passes. England, the mistress of so many wide and unpeopled lands, over which the dwellings of her adventurous sons are hereafter to be scattered, on which their toil is to be expended, and the glory of their motherland by their exertions to be perpetuated—England should especially encourage all such learning, and the sons of English farmers should willingly avail themselves of every opportunity of acquiring it.

Subdivisions of Stratified Rocks.—The thousands of beds or strata lying one over the other in the crust of the globe, have—partly for convenience and partly in consequence of certain remarkably distinctive characters observed among them—been sepa-

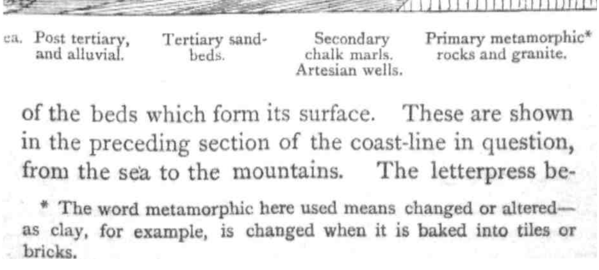
rated by geologists into three great divisions. The *primary* are oldest, and in general the lowest; the *secondary* lie over these; and the *tertiary* are the uppermost, and have been most recently formed. The sands, gravels, clays, and alluvial deposits, which in many places overlie the solid rocks and the beds of soft limestone, in many places formed by calcareous springs, are often spoken of as *post-tertiary*.

In some countries, on the surface of which these several divisions of the strata are seen to succeed each other very closely, the character of the surface-soil and its agricultural capability are also seen to vary as we pass from the rocks of the one epoch to those of the other. This is the case, for example, in the more southerly of the United States of America which lie along the Atlantic border. As we walk inland from the sea-shore, we pass over low and swampy, but rich muddy flats, which yield large returns of sea-island cotton and rice. As we proceed, the ground gradually rises above the sea-level—becomes firmer and drier—and instead of the swamp willow and cypress, bears the hickory and the oak. Tobacco and sugar are the marketable crops on this drier land, and Indian corn the staple food of the coloured population. After twenty miles or so, the edge of this drier alluvial plain is reached, and we ascend a low escarpment or terrace of yellow sand. Here we find our selves amid thin forests of unmixed natural pine, growing upon a poor sandy soil; and till we cross this belt and reach a second terrace, few corn-fields, or attempts at clearing for the purposes of cultivation, meet the eye. The new terrace presents the remarkable contrast of an open prairie. void of trees, cov-

ered with a thin soil waving with grass, and resting, like our English downs, on chalk rocks beneath. This tract is dry and deficient in water; but the thin soil, when turned over, yields crops of corn, and bears, among others, a variety of hard wheat, known in the market by the name of Georgian wheat. Still farther on this prairie is passed, and we ascend hilly slopes, upon which clays and loams of various qualities and capabilities occur at intervals intermingled, and broad-leaved trees of various kinds ornament the landscape. It is a country fitted for general husbandry, propitious to skill and industry, and, by its climate, adapted to the constitution of settlers of European blood.

These changes in agricultural character and capability are coincident with changes in the geological age

Fig. 16.



of the beds which form its surface. These are shown in the preceding section of the coast-line in question, from the sea to the mountains. The letterpress be-

* The word metamorphic here used means changed or altered—as clay, for example, is changed when it is baked into tiles or bricks.

low the section indicates the geological formations; that placed above it indicates, first, the natural vegetation, and then the kind of husbandry and of labour which are best adapted to each.

In studying the foregoing paragraphs, the reader will have observed a close general relation between the changes in geological and agricultural character which appear on the several successive terraces or flats of land which intervene between the shores of the Atlantic and the slopes of the Alleghany Mountains. Where the most recent or alluvial loams and rich clay end, there the tobacco, Indian corn, and even wheat culture, for the time, end also. The tertiary sands belong to a more ancient epoch, and to them are limited, by a strictly-defined boundary on each side, the dark pine-forests which are so striking a feature of the country. On the still older chalk, again, the treeless prairie and flinty wheat country is as distinctly limited by the formations on either hand, and beyond this, again, the changed forests and cultivation of the higher country are determined by the change in nature and in age which the rocks of this region exhibit.

CHAPTER IX.

SUBDIVISION OF ROCKS.

The several great groups of strata of which we have spoken under the names of primary, secondary, &c., are themselves broken up or subdivided by geologists

into a variety of subdivisions called systems and formations, each of which possesses its peculiar mineral characters and special agricultural relations. These, in so far as relates to the geology of our own country, it will be proper briefly to indicate.

The Tertiary Strata.—The tertiary strata, as they occur in England, consist chiefly of the crag, which lies above, and the London and plastic clays, which follow each other underneath.

1. The *Crag* consists of a mass of rolled pebbles mixed with marine shells and corals, and resting upon beds of sand and marl. It is in places as much as 50 feet in thickness, though generally of less depth, and forms a strip of flat land, a few miles in width, along the eastern shores of Norfolk and Suffolk. The soil is generally fertile, but varies in value from 5s. to 25s. an acre of rent.

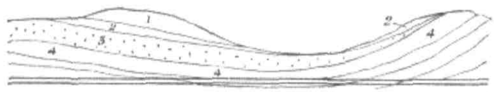
This crag is chiefly interesting to the agriculturist from its containing hard, rounded, flinty nodules—often spoken of as *coprolites*—in which as much as 60 per cent of calcium phosphate (bone-earth) is frequently found. These nodules are scattered through the body of the marls, and through the subsoils of the fields far inland, and are collected for sale to the manufacturers of superphosphate of lime, and other artificial manures. Many thousands of tons are raised annually.*

* The cost of digging up, screening, cleaning, &c., of those nodules, is about 5s. a ton, and they are delivered on board the vessel at 30s. to 45s. The quantity of the fossils which is scattered over this part of the county, and the treasure they are now proving to the owners of the land, may be judged of from two facts stated by Mr Herapath (Jour. Royal Agric. Soc., xii. 93), "that £60, £70, and £80 have been repeatedly given for leave to dig over a two-

2. The *London and Plastic Clays*, from 500 to 900 feet thick, consist of stiff, almost impervious, dark-coloured clays—the soils formed from which are still chiefly in pasture. The lower beds—the plastic clay—are mixed with sand, and produce an arable soil; but extensive heaths and wastes rest upon them in Berkshire, Hampshire, and Dorset. The crops of corn and roots yielded by the stiff clay soils of these strata have hitherto, in many districts, been found insufficient to pay the cost of raising them. The drain and the subsoil plough, with lime or chalk—in which these clays are very deficient, and for the addition of which they are very grateful—would render them more productive and more profitable to the farmer.

The Secondary Strata.—3. The *Chalk*, about 600 feet in thickness, lies below the London and plastic clays above described. It consists—as shown in the section, fig. 17—in the upper part, of a purer chalk

Fig. 17.



1. London clay.
2. Plastic clay.
3. Upper chalk, with flints.
4. Under chalk, without flints.

with layers of flint (3); in the lower, of a marly chalk without flints (4). The soil of the upper chalk is chiefly in sheep-walks; that of the lower chalk is

acre field;" and "that the land itself is actually improved by the course of treatment to which it is subjected when excavating for the fossils."

very productive of corn. In some localities (Croydon) the arable soils of the upper chalk have lately been rendered much more productive in corn and beans by deep ploughing, and thus mixing with the upper soil as much as 6 or 8 inches of the inferior chalk. Excellent crops of carrots also have been obtained by deep-forking such land.

The general and comparative agricultural value of the soils upon the chalk may, to a certain extent, be judged of by the fact, that in the lowest-rented counties in England chalk is the prevailing rock.

4. The *Greensand*, 500 feet thick, consists of 150 feet of clay, with about 100 feet of a greenish, more or less indurated, sand above, and 250 feet of sand or sandstone below it. The upper sand forms a very productive arable soil; but the clay forms impervious, wet, and cold lands, chiefly in pasture. The lower sand is generally unproductive.

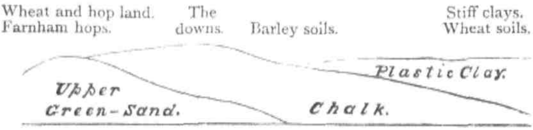
In the greensand, both upper and lower, but especially in the upper, beds of marl occur, in which are found layers of so-called coprolites and other organic remains, rich in phosphate of lime. To the presence of these beds is ascribed the fertility of the soil of the upper greensand, which in some localities is very remarkable, and, as at Farnham in Surrey, is found to be especially favourable to the growth of hops. The organic remains are in some places so abundant that, as in the crag, they are sought for and dug up, as a natural source of the phosphate of lime, usually supplied to the soil directly in the form of bones.

It is an important agricultural remark, that where the plastic clay comes in contact with the top of the chalk, an improved soil is produced; and that where

the chalk and the greensand mix, extremely fertile patches of country present themselves.

The following imaginary section shows the relative positions of these two fertile strips of country, above

Fig. 18.



and below the chalk. At the contact with the plastic clay it is particularly adapted for the growth of barley, which, for quality and malting properties, is not excelled by any in the kingdom. In Essex, barley grown on this soil is principally sold to maltsters at Stortford, &c.; and when malted, is sold again in London under the name of Ware malt. This name is derived from Ware in Hertfordshire, a market town standing on a similar soil.

The soils at the contact of the chalk and upper greensand are celebrated for their crops of wheat, in producing which the phosphates in the marls of the upper greensand are supposed to have some influence.

5. The *Wealden formation*, which succeeds the greensand, is nearly 1000 feet thick, and consists of 400 feet of sand, covered by 300 of clay, resting upon 250 of marls and limestones. The clay forms the poor, wet, but improvable pastures of Sussex and Kent. These clays, in many places, harden like a brick when dried in the air; and clods which have lain long in the sun, ring, when struck, like a piece of pottery. By draining alone, their produce has been

raised from 16 to 40 bushels of wheat an acre. On the sands below the clay rest heaths and brushwood; but where the marls and limestones come to the surface, the land is of better quality, and is susceptible of profitable arable culture.

6. In the *Upper Oolite*, of 600 feet in thickness, we have a bed of clay (Kimmeridge clay) 500 feet thick, covered by 100 feet of sandy limestones. The clay lands of this formation are difficult and expensive to work, and are therefore chiefly in old pasture. The sandy limestone soils above the clay are also poor; but where they rest immediately upon, and are intermixed with, the clay, excellent arable land is produced.

7. The *Middle Oolite*, of 500 feet, consists also of a clay (Oxford clay), dark blue, adhesive, often rich in lime, and nearly 400 feet thick, covered by 100 feet of limestones and sandstones. These latter produce good arable land where the lime happens to abound, but the clays, especially while undrained, form close, heavy, compact soils, most difficult and expensive to work. In wet weather they are often adhesive like bird-lime, and in dry summers become hard like stone, so as to require a pick-axe to break them. They have, therefore, hitherto been very partially brought into arable culture. The extensive pasture-lands of Bedford, Huntingdon, Northampton, Lincoln, Wilts, Oxford, and Gloucester, rest chiefly upon this clay; as do also the fenny tracts of Lincoln and Cambridge. The use of burned clay upon the arable land has, in some parts of this clay district, been of much advantage.

8. The *Lower*, or *Bath Oolite*, of 500 feet in thick-

ɛss, consists of many beds of limestone and sand- :one, with about 200 feet of clay in the centre of the ɔrmation. The soils are very various in quality, ccording as the sandstone or limestone predominates n each locality. The clays are chiefly in pasture; :he rest is more or less productive, easily-worked, arable land. In Gloucester, Northampton, Oxford, the east of Leicester, and in Yorkshire, this formation is found to lie immediately beneath the surface, and a little patch of it occurs also on the south-eastern coast of Sutherland.

9. The *Lias* is an immense deposit of blue clay with limestones, from 500 to 1000 feet in thickness, which produces cold, blue, unproductive clay soils. It forms a long strip of land, of varying breadth. which extends, in a south-western direction, from the mouth of the Tees in Yorkshire, to Lyme Regis in Dorset. It is chiefly in old, and often very valuable, pasture. An efficient system of drainage is converting much of this clay into most productive wheat land.

10. The *New Red Sandstone*, though only 500 feet in thickness, forms the surface of nearly the whole central plain of England, and stretches northwards through Cheshire to Carlisle and Dumfries. It consists of red sandstones and red marls, the soils produced from which are easily and cheaply worked, and form some of the richest and most productive arable lands in the island. This is in some degree indicated by the fact that the three highest-rented counties in England rest chiefly upon this rock. Ir whatever part of the world the red soils of this for mation have been met with, they have been foun‹

to possess in general the same valuable agricultural capabilities.

11. The *Magnesian Limestone*, from 100 to 500 feet in thickness, is covered by a strip of generally poor thin soil, extending from Durham to Nottingham, capable of improvement as arable land by high farming, but bearing naturally a poor pasture, intermingled sometimes with magnificent furze.

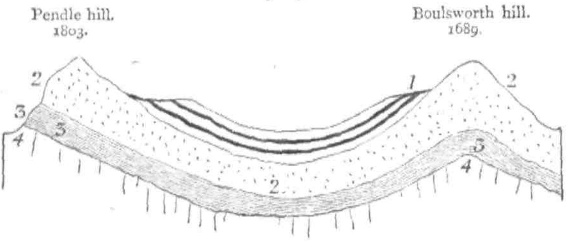
12. The *Coal-measures*, from 300 to 3000 feet thick, consist of beds of grey sandstone, and of dark-blue shale, or hardened clay, intermingled (*interstratified*) with beds of coal. Where the sandstones come to the surface, the soil is thin, poor, hungry, sometimes almost worthless. The shales, on the other hand, produce stiff, wet, almost unmanageable clays —not unworkable, yet expensive to work, and requiring draining, lime, skill, capital, and a zeal for improvement to be applied to them, before they can be made to yield the remunerating crops of corn they are capable of producing. The blaes or shales of this formation, when dug out of cliffs or brought from coal-mines, may be laid with advantage on loose sandy soils, and even, it is said, on the stiff whitish clays almost destitute of vegetable matter, which, as in Lanarkshire, occasionally occur on the surface of our coal-fields.

13. To the *Millstone-grit*, of 600 feet or upwards in thickness, the same remarks apply. It lies below the coal, but is often only a repetition of the sandstones and shales of the coal-measures, and forms in many cases soils still more worthless. Where the sandstones prevail, large tracts lie naked, or bear a thin and stunted heath. Where the shales abound,

the naturally difficult soils of the coal-shales agair recur. The rocks of this formation generally ap proach the surface, around the outskirts of our coal fields.

This arises from the circumstance that our coal-measures often lie in basin-shaped deposits, from beneath each edge of which, the millstone-grit and mountain-limestone rocks rise up to the surface. This is illustrated by the annexed section (fig. 19) across a part of Lancashire, in which 1 represents the coal-measures; 2, the coarse sandstones, &c., of

Fig. 19.



the millstone-grit; 3, a thick shale-bed, which often overlies the thick masses of mountain-limestone represented by 4.

The traveller passes off the poor, often cold and wet, clay soils of the coal-measures, on to the equally poor lands of the millstone-grit, and over its top, as at Pendle hill, descends upon the sweet herbage and rich dairy pastures of the mountain-limestone at 4.

The section shows also how in this country the millstone-grit often rises into high hills. These are then covered with poor heaths and worthless moors,

while limestone hills of equal height bear green herbage to the very top.

14. The *Mountain-limestone*, 500 to 2000 feet thick, is a hard blue limestone rock, separated here and there into distinct beds by layers of sandstones, of sandy slates, or of bluish-black shales like those of the coal-measures. The soil upon the limestone is generally thin, but produces a naturally sweet herbage, everywhere superior in value to that which grows on the sandier soils of the millstone-grit. When the limestone and clay (shale) adjoin each other, as where 3 and 4 in the section meet, arable land occurs, which is naturally productive of oats, and, where the climate is favourable, may, by skilful treatment, be converted into good wheat land. In the north of England—in Derbyshire, for example, and among the Yorkshire dales—a considerable tract of country is covered by these rocks; but in Ireland they form nearly the whole of the interior of the island.

15. The *Old Red Sandstone* varies in thickness from 500 to 10,000 feet. It possesses many of the valuable agricultural qualities of the *new red* (No. 10), consisting, like it, of red sandstones and red marls, which crumble down into rich red soils. Such are the soils of Brecknock, Hereford,* and part of Monmouth; of part of Berwick and Roxburgh; of Haddington and Lanark; of southern Perth; of either shore of the Moray Firth: and of part of Sutherland, Caithness, and the Orkney Islands. In Ireland, also, these rocks abound in Tyrone, Fermanagh, and

* On the concretionary limestones or cornstones which form subordinate beds in this formation, grow the finest orchards of Herefordshire and its best oaks.

Monaghan; in Waterford, in Mayo, and in Tipperary. In all these places the soils they form are generally the best in their several neighbourhoods. Here and there, however, where the sandstones are harder, more silicious and impervious to water, tracts, sometimes extensive, of heath and bog occur; while in others the rocks have crumbled into hungry sands, which swallow up the manure, and are expensive to maintain in arable culture.

The Primary Strata.—The primary stratified rocks, which lie underneath all those already described, are separable into three natural divisions: the *Silurian* * above, which contain the remains of animals in a fossil state; the *Cambrian* † below, in which few animal remains have yet been discovered; and lowest of all, the *mica-slate* and *gneiss* rocks, which exhibit marks of change or alteration by the agency of heat. Hence these last are often spoken of as *metamorphic*, or changed rocks.

16. The *Upper Silurian system* is nearly 4000 feet in thickness, and forms the soils which cover the lower border counties of Wales. It consists of sandstones and shales, with occasional limestones; but the soils formed from these beds take their character from the general abundance of the clay. They are cold—usually unmanageable *muddy* clays; with the remarkably inferior agricultural value of which the traveller is immediately struck, as he passes westward from the red sandstones of Hereford to the Upper Silurian rocks of the county of Radnor.

* Or older *Palæozoic*, as containing evidences of most ancient life.

† Or *Azoic*, from containing few traces of life.

17. The *Lower Silurian* rocks are many thousand feet in thickness, and in Wales lie to the west and north of the Upper Silurian rocks. They consist, on the upper part, of about 25,000 feet of sandstone, on which, when the surface is not naked, barren heaths alone rest.

Beneath these sandstones lie 1200 feet of sandy and earthy limestones, from the decay of which, as may be seen on the southern edge of Caermarthen, fertile arable lands are produced.

The high land, which stretches across the whole ot southern Scotland, from St Abb's Head to Portpatrick, including the Lammermuir Hills, so far as they have yet been examined, consists of strata belonging to the upper part of the Lower Silurian, and the lower part of the Upper Silurian. The soils in general are of inferior quality, the slaty rocks crumbling with difficulty, and being poor in lime. Cold and infertile farms cover the higher grounds, and wide heathy moors and bogs.

18. The *Cambrian system* is at present a subject of dispute among geologists, and its limits even in our own island are not well defined. It is probably many thousand feet in thickness—lies beneath the Lower Silurian—and in its agricultural relations has much resemblance to these rocks. It consists in great part of slaty rocks, more or less hard, which often crumble very slowly, and almost always produce either poor and thin soils—or cold, difficultly manageable clays, expensive to work, and requiring *high farming* to bring them into profitable arable cultivation. In Cornwall, western Wales, the mountains of Cumberland; in the mountains of Tipperary, in the

extreme south of Ireland, on its east coast, and far inland from the bay of Dundalk, such slaty rocks occur, though the limits of the two formations have not been everywhere defined. Patches of rich, well-cultivated land occur here and there in these districts, with much also that is improvable; but the greater part is usurped by worthless heaths and extensive bogs. On the difficult soils of these formations—thinly peopled, inhabited by small farmers with little capital, and therefore hitherto neglected—much improvement is now here and there appearing; and the introduction of the drain promises to make much corn grow, where little food, either for man or beast, was previously produced. These rocks in general contain little lime, and therefore, after the drain, the addition of lime is usually one of the most certain means of increasing the productiveness of the soils formed from them.

19. The *Mica-slate* and *Gneiss systems* are of unknown thickness, and consist chiefly of hard and slaty rocks, crumbling slowly, forming poor, thin soils, which rest on an impervious rock, and which, from the height to which this formation generally rises above the level of the sea, are rendered more unproductive by an unpropitious climate. They form extensive heathy tracts in Perth and Argyle, and on the north and west of Ireland. Here and there only—in the valleys or sheltered slopes, and by the margins of the lakes—spots of bright green meet the eye, and patches of a willing soil, fertile in corn.

Relations of Geology to Agriculture.—A careful perusal of the preceding sketch of the general agricultural capabilities of the soils formed from the several

classes of stratified rocks, will have presented to the reader many illustrations of the facts stated in the previous chapter. He will have drawn for himself—to specify a few examples—the following among other conclusions :—

1. That some formations, like the new red sandstone, yield a soil almost always productive ; others, as the coal-measures and millstone-grits, a soil almost always *naturally* unproductive ; and others, again, like the mountain-limestone, a short sweet herbage, grateful to cattle, and productive of butter and cheese.

2. That good land—or better, at least, than generally prevails in a district—may be expected where two formations, or two different kinds of rock, meet. As when a limestone and a clay mingle their mutual ruins for the formation of a common soil.*

3. That in almost every country extensive tracts of land, on certain formations, will be found laid down to natural grass, *in consequence of the original difficulty and expense of working*. Such are the Lias, the Oxford, the Weald, the Kimmeridge, and the London clays. In raising corn, it is natural that the lands which are easiest and cheapest worked should be first subjected to the plough. It is not till implements are improved, skill increased, capital accumulated, and population presses, that the heavier lands in a country are rescued from perennial grass, and made to produce that greatly-increased amount of food for both man and beast, which they are easily capable of yielding.

4. That the rotations adopted in a district, though faulty, and, in the eyes of improved agriculture, de-

* See fig. 18, p. 104.

serving of condemnation, are often not only determined, but rendered necessary, by the natural structure of the country. When cold clays refuse to bear even average crops of any other kinds than wheat and beans, the old European rotation of wheat, beans, fallow—which in this country has prevailed, in many places, since the times of the ancient Britons—becomes almost a necessity to the farmer. It is unfair to blame his rotations, or accuse him of prejudice and ignorance in clinging to them, till the natural condition of the land has been altered by art, so as to fit it for the profitable growth of other crops.

The turnip and barley soils of Great Britain are in many districts, it may be, but indifferently farmed; and the State has reason to complain of much individual neglect of known and certain methods of increasing their productiveness. But *the great achievement which British agriculture has now to effect is to subdue the stubborn clays, and to convert them into, what many of them are yet destined to become, the richest corn and green-crop bearing lands in the kingdom.*

5. That there are larger tracts of country still—such as rest on the slates of the Lower Silurian and Cambrian systems, for example—from which the efforts of the enlightened agriculturist have hitherto been withheld, in consequence of the apparent hopelessness of ever bringing them into profitable culture. Over these tracts, however, there are large portions which will pay well for skilful improvement. Make roads and drains, bring in lime, and manure well. You will thus improve the soil, gradually ameliorate the climate, make modern skill and improvements available, obtain a remunerating return for labour econo-

mically expended, and for capital judiciously invested, and you will at the same time increase the power and the resources of the country.

CHAPTER X.

THE RELATION BETWEEN SOILS AND THE ROCKS FROM WHICH THEY WERE FORMED.

It was stated in a preceding chapter that rocks are divided by geologists into the stratified and the *unstratified.* The unstratified are often called *crystalline* rocks, because they frequently have a glassy appearance, or contain regular crystals of certain mineral substances; often also *igneous* rocks, because they appear all to have been originally in a melted state, or to have been produced by fire. The stratified rocks cover by far the largest portion of the globe, and form the great variety of soils, of which a general description has just been given. The unstratified rocks are of two kinds—the *granites* and the *trap* rocks; and as a considerable portion of the area of Great Britain and Ireland is covered by them, it will be proper shortly to consider the peculiar characters of each, and the differences of the soils produced from them.

1. The *Granites* consist of a mixture, in different proportions, of three minerals, known by the names of *quartz*, *felspar*, and *mica*. The latter, however, is

generally present in such small quantity, that in our general description it may be safely left out of view. Granites, therefore, consist chiefly of quartz and felspar, in proportions which vary very much; but the former, on an average, constitutes perhaps from one-third to one-half of the whole.

Gneiss resembles granite in composition, but presents a somewhat stratified appearance. When hornblende replaces mica in granite, the rock is termed *syenite.*

Quartz has already been described as being the same substance as flint, or the silica of the chemist. When the granite decays, this portion of it forms a more or less coarse silicious sand.

Felspar is a white, greenish, or flesh-coloured mineral, often more or less earthy in its appearance, but generally hard and brittle, and sometimes glassy. It is scratched by quartz, and thus is readily distinguished from it. When felspar decays, it forms an exceedingly fine tenacious clay (pipe-clay).

Granite generally forms hills, and sometimes entire ridges of mountains. When it decays, the rains and streams wash out the fine felspar clay, and carry it down into the valleys, leaving the quartz sand on the sides of the hills. Hence the soil in the bottoms and flats of granite countries consists of a cold, stiff, wet, more or less impervious clay, which, though capable of much improvement by draining, often bears only heath, bog, or a poor and unnutritive pasture. The hillsides are either bare, or are covered with a thin, sandy, and ungrateful soil, of which little can be made without the application of much skill and industry. Yet the opposite sides of the same moun-

tains often present a remarkable difference in this respect; those which are most beaten by the rains having the light clay most thoroughly washed from their surfaces, and being therefore the most sandy and barren.

2. The *Trap* rocks, comprising the greenstones and basalts—both sometimes called *whin*-stones—consist essentially of felspar and *hornblende*, or *augite*. In contrasting the trap rocks with the granites, it may be stated *generally*, that while the granites consist of felspar and *quartz*, the traps consist of felspar and *hornblende* (or augite). In the traps, both the felspar and the hornblende are reduced, by the action of the weather, to a more or less fine powder, affording materials for a soil; in the granites, the felspar is the principal source of the fine earthy matter they are capable of yielding. If we compare together, therefore, the chemical composition of the two minerals (hornblende and felspar), we shall see in what respect these two varieties of soil ought principally to differ. Thus they consist respectively of—

	Felspar.	Hornblende.
Silica,	65	52
Alumina,	18	12
Potash and soda,	17	trace.
Lime,	trace.	10
Magnesia,	do.	15
Oxides of iron,	do.	10½
Oxide of manganese,	do.	½
	100	100

A remarkable difference appears thus to exist, in chemical composition, between these two minerals—a difference which must affect also the soils produced

shells which are mixed with the town dung laid on by the Edinburgh farmers. Another important reason, however, is the abundance of lime contained in the trap rocks from which the soils are formed, and of which they contain so many fragments.

d. Why, as in many parts of the counties of Ayr and Fife, the application of lime is found to be useful when the trap soils are first broken up or reclaimed, but to produce little sensible benefit for twenty or thirty years afterwards, however frequently applied. In these cases the lime has been washed out of the surface-soil, and from the thoroughly-decayed parts of the trap, so that, when first broken up, lime is necessary to supply the deficiency. But the constant turning up of the soil by the after-cultivation exposes fresh portions of trap to the air, the decay of which annually supplies a quantity of lime to the soil from the rocky fragments themselves, and renders further artificial applications less necessary. We have picked up a piece of decaying trap, of which the outer portion contained scarcely any lime, while the central kernel contained a large proportion. The plough and harrow break up such decaying masses, and expose the undecomposed kernels to the weathering action of the atmosphere, and to the roots of the growing crops.

3. The *Lavas*, which often cover large tracts of country, where active or extinct volcanoes exist, are composed essentially of the same mineral substances as the trap rocks. These latter, indeed, are in general only lavas of a more ancient date. Like the traps, the lavas not unfrequently abound in hornblende or augite, and consequently in lime. They also crum-

ble, with various degrees of rapidity, when exposed to the air, and in Italy and Sicily often form soils of the most fertile description. Like the traps also, when in a decayed state, they may be advantageously employed for the improvement of less fruitful soils. In St Michael's, one of the Azores, the natives pound the volcanic matter and spread it on the ground, where it speedily becomes a rich mould, capable of bearing luxuriant crops.

Transported Soils.—It is necessary to guard the reader against disappointment when he proceeds to examine the relations which exist between the soils and the rocks on which they lie, or to infer the quality of the soil from the known nature of the rock on which it rests—in conformity with what has been above laid down—by explaining another class of geological appearances, which present themselves not only in our own country, but in almost every other part of the globe.

The unlearned reader of the preceding section and chapter may say, I know excellent land resting upon the granites, fine turnip soils on the Oxford or London clays, tracts of fertile fields on the coal-measures, and poor gravelly farms on the boasted new red sandstone: I have no faith in theory—I can have none in theories which are so obviously contradicted by natural appearances. Such, it is to be feared, is the hasty mode of reasoning among too many locally excellent practical men—familiar, it may be, with many useful and important facts, but untaught to look through and beyond isolated facts to the principles on which they depend. By *locally* excellent, we mean those who are the best possible farmers on

their own districts and after their own way, but who would fail in other districts requiring other methods. To the possessor of agricultural principles, the modifications required by difference of crop, soil, and climate, readily suggest themselves, where the mere practical man is bewildered, disheartened, and in despair.

Every one who has lived long on the more exposed shores of our island, has seen that, when the weather is dry and the sea-winds blow strong, the sands of the beach are carried inland and spread over the soil, sometimes to a considerable distance from the coast. In some countries this sand-drift takes place to a very great extent, travels over a great stretch of country, and gradually swallows up large tracts of fertile land, and converts them into sandy deserts.

Again, most people are familiar with the fact, that during periods of long-continued rain, when the rivers are flooded and overflow their banks, they not unfrequently bear with them loads of sand and gravel, which they carry far and wide, and strew at intervals over the surface-soil.

So the annual overflowings of the Nile, the Ganges, the Mississippi, and the Amazons, gradually deposit accumulations of soil over surfaces of great extent; —and so also the bottoms of most lakes are covered with thick beds of sand, gravel, and clay, which have been conveyed from the higher grounds by the rivers which flow into them. Over the bottom of the sea, also, the ruins of the land are spread. Torn by the waves from the crumbling shore, or carried down from great distances by the rivers which lose themselves in the sea, they form beds of mud, or banks of sand and gravel of great

extent, which cover and conceal the rocks on which they lie.

To these and similar agencies, a large portion of the existing dry land of the globe has been, and is still, exposed. Hence, in many places, the rocks and the soils naturally derived from them are buried beneath accumulated heaps or layers of sand, gravel, and clay, which have been brought from a greater or less distance, and which have not unfrequently been derived from rocks of a totally different kind from those of the districts in which they are now found. On these accumulations of *transported* materials, a soil is produced which often has no relation in its characters to the rocks which cover the country; and the nature of which soils, therefore, a familiar acquaintance with the rocks on which they immediately rest would not enable us to predict.

To this cause is due that discordance between the first indications of geology, as to the origin of soils from the rocks on which they rest, and the actually observed characters of those soils in certain districts —of which discordance mention has been made as likely to awaken doubt and distrust in the mind of the less instructed student, in regard to the predictions of agricultural geology There are several circumstances, however, by which the careful observer is materially aided in endeavouring to understand what the nature of the soils is likely to be in any given district, and how they ought to be treated even when the subjacent rocks are thus overlaid by masses of drifted materials. Thus—

1. It not unfrequently happens that the materials brought from a distance are more or less mixed up

with the fragments and decayed matter of the rocks which are native to the spot,—so that, though modified in quality, the soil nevertheless retains the general characters of that which is formed in other places from the decay of these rocks alone.

2. Where the formation is extensive, or covers a large area,—as the new red sandstones and coal-measures do in this country, the mountain-limestones in Ireland, and the granites in the north of Scotland,—the transported sand, gravel, or clay, strewed over one part of the formation, has not unfrequently been derived from the rocks of another part of the *same* formation; so that, after all, the soils may be said to be produced from the rocks on which they rest, and may be judged of from the known composition of these rocks.

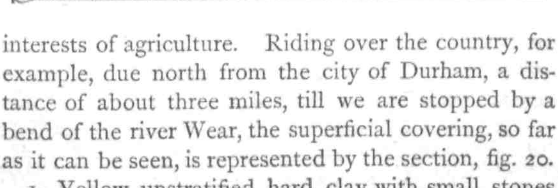
3. Or if not from rocks of the same formation, they have most frequently been derived from those of a neighbouring formation—from rocks which are to be found at *no great distance geologically*, and generally on higher ground. Thus the ruins of the millstone-grit rocks are in this country often spread over the surface of the coal-measures—of these, again, over the magnesian limestone—of the latter over the new red sandstone, and so on. The effect of this kind of transport of the loose materials upon the character of the soils is merely to overlap, as it were, the edges of one formation with the proper soils of the formations that adjoin it, in the particular direction from which the drifted materials are known to have come.

It appears, therefore, that the occurrence on certain spots, or tracts of country, of soils that have no apparent relation to the rocks on which they immedi-

ately rest, tends in no way to throw doubt upon, to discredit or to disprove, the conclusions drawn from the more general facts and principles of geology. It is still generally true that soils *are* derived from the rocks on which they rest. The exceptions are local, and the difficulties which these local exceptions present require only from agricultural geologists a more careful study of the structure of each district,—of the direction of the high lands—the nature of the slopes—the course and width of the valleys—and the extent of the plains,—before they pronounce a decided opinion as to the degree of fertility which the soil either naturally possesses, or by skilful cultivation may be made to attain.

It is not to be denied, however, that the practical importance of these local exceptions is becoming every day more manifest, and the necessity more apparent for a careful recording and mapping of them in the

Fig. 20.



interests of agriculture. Riding over the country, for example, due north from the city of Durham, a distance of about three miles, till we are stopped by a bend of the river Wear, the superficial covering, so far as it can be seen, is represented by the section, fig. 20.

1. Yellow unstratified hard clay with small stones

the geological structure determines more. In such a climate, and with a soil so naturally arid, abundant water is indispensable; but this can only be obtained by deep boring, performed at a great expense. The geological conditions, therefore, confine the possibility of cultivation to men of large means, and, in present circumstances at least, necessarily exclude all petty farming, and the subdivision of the land into small holdings. They determine, in other words, the social condition of the people. This single illustration is enough of itself to satisfy any impartial person of the close general relation which exists between the geological character and the agricultural capability of a country, and of the broad general deductions in regard to its possible future prosperity—in a rural sense—which may be drawn from a knowledge of its geology. We believe it is partly under the influence of this conviction that the Senate and Congress of the United States have so often and so cordially voted large sums of money for the purpose of investigating and mapping the main geological features of the new States and territories which from time to time have been admitted into the Union.

Geological *maps*, such as those now referred to, indicate with more or less precision the extent of country over which the chalk, the red sandstone, the granites, &c., are found immediately beneath the loose materials on the surface. Such maps, therefore, are of great value in indicating also the general quality of the soils over the same districts. It may be true, as we have above explained, that here and there the *natural* soils are masked or buried by transported materials — yet the *political economist* may,

nevertheless, with safety estimate the general agricultural capabilities and resources of a country by the study of its geological structure—the *capitalist* judge in what part of it he is likely to meet with an agreeable or profitable investment—and the *practical farmer* in what country he may expect to find land that will best reward his labours, that will admit of the kind of culture to which he is most accustomed, or, by the application of better methods, will manifest the greatest agricultural improvement.

CHAPTER XI.

THE PHYSICAL PROPERTIES OF SOILS—FERTILE AND BARREN SOILS.

Soils formed, as we have described, from the ruins of crumbled rocks, more or less sorted and drifted by water, possess three classes of properties, intimately related to each other, and to their special agricultural value. These are their *physical*, *chemical*, and *botanical* properties. A brief consideration of two of these will form the subject of the present chapter.

The Physical Properties of Soils. — The chief physical properties of soil which are of interest to agriculturists are their density, or specific gravity; their capacity for absorbing and retaining moisture; their porosity; and their temperature under varying conditions.

1°. *Density.*—Some soils are heavier than others, sands and marls weighing most, and dry peaty soils the least. The specific gravity or relative weight of sands is about twice that of water. Strange as it may appear, it is a fact that a stiff clay is about one-fourth lighter than an equal volume of a sandy soil. This density is of so much practical importance, that treading with sheep and other stock is resorted to in many districts, with the view of rendering the land more solid; or heavy rollers are passed over it, to prepare a firm seed-bed for the corn. Also, in reclaiming peaty soils, it is found highly beneficial to increase their density by a covering of clay or sand, or of limestone gravel, as is the practice in Ireland. A stiff clay has been found to retain 50 per cent of water, and yet to appear quite dry. On the other hand, pure sands will hardly retain 5 per cent of their weight of moisture.

2°. *Absorption of water.*—Again, some soils absorb the rains that fall, and retain them in larger quantity and for a longer period than others. Strong clays absorb and retain nearly three times as much water as sandy soils do, while peaty soils absorb a still larger proportion. Hence the more frequent necessity for draining clayey than sandy soils; and hence also the reason why, in peaty land, the drains must be kept carefully open, in order that the access of springs and of other water from beneath may be as much as possible prevented.

In seasons of prolonged drought cattle often find abundance of herbage in low-lying, undrained pastures. It is only at such times that these pastures are of much value.

3°. The *capillary action* of soils also differs. Some, when immersed in water, will become moist, or attract the water upwards for 10 or 12 inches, some as many as 16 or 18 inches, above the surface of the water. This property is of great importance in reference to the growth of plants—to the rising of water to the surface of land which rests upon a wet subsoil—to the necessity for thorough drainage—to the general warmth of the soil, and so on.

4°. *Evaporative power.*—When dry weather comes, soils lose water by evaporation with different degrees of rapidity. In this way a silicious sand will give off the same weight of water, in the form of vapour, in one-third of the time necessary to evaporate it from a stiff clay, a peat, or a rich garden-mould, when all are equally exposed to the air. Hence the reason why plants are so soon burned up in a sandy soil. Not only do such soils *retain* less of the rain that falls, but that which is retained is also more speedily dissipated by evaporation. When rains abound, however, or in very moist seasons, these same properties of sandy soils enable them to dry quickly, and thus to sustain a luxuriant vegetation at a time when plants will perish on clay lands from excess of moisture.

5°. *Shrinkage.*—In drying under the influence of the sun, soils shrink in, and thus diminish in bulk, in proportion to the quantity of clay or of peaty matter they contain. Sand scarcely diminishes at all in bulk by drying, but peat shrinks one-fifth in bulk, and strong agricultural clay nearly as much. The roots are thus compressed and the air excluded from them, especially in the hardened clays, in very dry weather, and the plant is thereby placed in a condition

remarkable similarity in physical properties between stiff clay and peaty soils. Both retain much of the water that falls in rain, and both part with it slowly by evaporation. Both contract much in drying, and both absorb moisture readily from the air, in the absence of the sun. In this similarity of properties we see not only why the first steps in improving both kinds of soil must be very nearly the same, but why, also, a mixture either of clay or of vegetable matter will equally impart to a sandy soil many of those elements of fertility—of which they are alike possessed.

Chemical Composition of Soils.—Soils perform at least three functions in reference to vegetation. They serve as a basis in which plants may fix their roots and sustain themselves in their erect position—they supply food to vegetables at every period of their growth—and they are the medium in which many chemical changes take place, that are essential to a right preparation of the various kinds of food which the soil is destined to yield to the growing plant.

We have spoken of soils as consisting chiefly of sand, lime, and clay, with certain saline and organic substances in smaller and variable proportions. But the study of the ash of plants (see chap. iv.) shows us that a fertile soil, besides its organic matter, must of necessity contain an appreciable quantity of twelve or fourteen different mineral substances, which, in most cases, exist in greater or less relative abundance in the ash both of wild and of cultivated plants.

The following analyses of wheat soils are given on the authority of the late Professor Anderson ('Transactions of the Highland and Agricultural Society,' July 1860) :—

Analyses of Soils.

100 parts contain—

	1.		2.	
	Soil.	Subsoil.	Soil.	Subsoil.
Silica,	74.5529	82.5874	61.1954	61.6358
Peroxide of iron,	5.1730	3.4820	4.8700	6.2303
Alumina,	6.9350	5.3250	14.0400	14.2470
Lime,	1.2290	0.9392	0.8300	1.2756
Magnesia,	1.0827	0.8366	1.0200	1.3938
Potash,	0.3544	0.1687	2.8001	2.1761
Soda,	0.4335	0.0649	1.4392	1.0450
Sulphuric acid,	0.0443	0.0970	0.0911	0.0396
Phosphoric acid,	0.4300	0.1970	0.2400	0.2680
Chlorine,	traces	traces	0.0098	0.0200
Organic matter,	10.1981	4.8358	8.5508	6.8270
Water,	2.6840	1.7670	2.7000	4.5750

No. 1 analysis refers to a soil immediately under the brow of Corstorphine Hill, Mid-Lothian, on the sandstone of the coal formation. The crops had been rather poor for some years previous to the time at which the soil was analysed. No. 2 refers to a soil in the Carse of Gowrie, Perthshire, and which produced excellent crops. The quantity of potash in this soil is quite remarkable. Here the application of kainit or other potash salts would indeed be a waste of material.

Two well-known geological facts lead to precisely the same conclusion. We have seen that the soils formed from the unstratified rocks—the granites and the traps—while they each contain certain earthy substances in proportions peculiar to themselves, yet contain also in general, especially the trap soils, a

trace of most of the other kinds of matter which are found in the ash of plants. Again, it is equally certain that the stratified rocks are only the more or less slowly accumulated fragments and ruins of more ancient stratified or unstratified masses, which, under various agencies, have gradually crumbled to dust, been strewed over the surface in alternate layers, and have afterwards again consolidated. The reader will readily grant, therefore, that in all rocks, and consequently in all soils, *traces* of every one of these substances may generally be presumed to exist.

Actual chemical analysis confirms these deductions in regard to the composition of soils. It shows that, in most soils, the presence of all the constituents of the ash of plants may be detected, though in very variable, and sometimes in very minute, proportions; and following up its investigations in regard to the effect of this difference in their proportions, it establishes certain other points of the greatest possible importance to agricultural practice. Thus it has found, for example—

1. That as a proper adjustment of the proportions of clay, sand, and vegetable matter is necessary in order that a soil may possess the most favourable *physical* properties, so the mere presence of the various kinds of food, organic and inorganic, in a soil, is not sufficient to make it productive of a given crop, but that they must be present in such quantity that the plant shall be able readily—at the proper season, and within the time usually allotted to its growth—to obtain an adequate supply of each.

Thus a soil may contain, on the whole, far more of a given ingredient, such as potash, soda, and lime,

than the crop we have sown may require; and yet, being diffused through a large quantity of earth, the roots may be unable to collect this substance fast enough to supply the wants of a rapidly-growing plant. To such a soil it will be necessary to add a further portion of what the crop requires.

Again, a crop of winter wheat, which remains nine or ten months in the field, has much more leisure to collect from the soils those substances which are necessary to its growth than a crop of barley, which in cold climates like that of Sweden is only from 6 to 7½ weeks in the soil, and which in warm countries like Sicily may be reaped twice in the year. Thus a soil which refuses to yield a good crop of the quick-growing barley may readily nourish a crop of slow-growing wheat.

2. That when a soil is particularly poor in certain of these substances, the valuable cultivated corn crops, grasses, and trees, refuse to grow upon them in a healthy manner, and to yield remunerating returns. And—

3. That when certain other substances are present in too great abundance, the soil is rendered equally unpropitious to the most important crops.

In these facts the intelligent reader will perceive the foundation of the varied applications to the soil which are everywhere made under the direction of a skilful practice—and of the difficulties which, in many localities, lie in the way of bringing the land into such a state as shall fit it readily to supply all the wants of those kinds of vegetables which it is the special object of artificial culture easily and abundantly to raise.

Chemical analysis is a difficult art—one which de-

mands much chemical knowledge, as well as skill in chemical practice (manipulation, as it is called), and requires both time and perseverance—if valuable, trustworthy, and minutely correct results are to be obtained. It is only the results of those chemical analyses which are conducted in the most conscientious spirit and with the utmost minuteness in details that are likely to throw light on the peculiar properties of those soils which, while they possess much general similarity in composition and physical properties, are yet found to possess very different agricultural capabilities. Many such cases occur in every country, and they present the kind of difficulties in regard to which agriculture has a right to say to chemistry—"These are matters which I hope and expect you will satisfactorily clear up." But while agriculture has a right to use such language, she has herself preliminary duties to perform. She has no right in one breath to deny the value of chemical theory to agricultural practice, and in another to ask the sacrifice of time and labour in doing her chemical work. Chemistry is a wide field, and many zealous lives are now being spent in the prosecution of it, without at all entering upon the domain of practical agriculture. It may be that here and there it may fall in with the humour or natural bias of some one chemist to apply his knowledge to this most important art; but hitherto the appreciation of such efforts has, except by a limited few, been so small—the reception of scientific results and suggestions by the agricultural body generally so ungracious,—that little wonder can exist that so many chemists have quitted the field in disgust—that the majority of capable men should studiously avoid it.

Composition of Fertile and Barren Soils.—With the view of illustrating the deductions which, as above stated, may be drawn from an accurate chemical analysis, we shall exhibit the composition of three different soils, as determined by Sprengel, a German agricultural chemist.

No. 1 is a very fertile alluvial soil from East Friesland, formerly overflowed by the sea, but for sixty years cultivated with corn and pulse crops *without manure.*

No. 2 is a fertile soil near Göttingen, which produces excellent crops of clover, pulse, rape, potatoes, and turnips, the two last more especially *when manured with gypsum.*

No. 3 is a very barren soil from Luneberg.

When washed with water in the manner described in page 82, they give respectively, from 1000 parts of soil—

	No. 1.	No. 2.	No. 3.
Soluble saline matter,	18	1	1
Fine clay and organic matter,	937	839	599
Silicious sand,	45	160	400
	1000	1000	1000

The most striking distinction presented by these numbers is the large quantity of saline matter in No. 1. This soluble matter consisted of common salt, chloride of potassium, sulphate of potassium, and sulphate of calcium (gypsum), with traces of sulphate of magnesium, sulphate of iron, and phosphate of sodium. The presence of this comparatively large quantity of these different saline substances—originally derived, no doubt, in great part from the sea—was probably

one reason why it could be so long cropped without manure.

The unfruitful soil is much the lightest (in the agricultural sense) of the three, containing 40 per cent of sand; but this is not enough to account for its barrenness, many light soils containing a larger proportion of sand, and yet being sufficiently fertile.

The finer portions, separated from the sand and soluble matter, consisted, in 1000 parts, of—

	No. 1.	No. 2.	No. 3.
Organic matter,	97	50	40
Silica,	648	833	778
Alumina,	57	51	91
Lime,	59	18	4
Magnesia,	8½	8	1
Oxide of iron,	61	30	81
Oxide of manganese,	1	3	½
Potash,	2	trace.	trace.
Soda,	4	do.	do.
Ammonia,	trace.	do.	do.
Chlorine,	2	do.	do.
Sulphuric acid,	2	¾	do.
Phosphoric acid,	4½	1¾	do.
Carbonic acid,	40	4½	do.
Loss,	14	—	4½
	1000	1000	1000

1. The composition of No. 1 illustrates the first of the general deductions stated in the preceding section—that a considerable supply, namely, of *all* the species of inorganic food is necessary to render a soil eminently fertile. Not only does this soil contain a comparatively large quantity of soluble saline matter, but it contains also nearly 10 per cent of organic matter, and what, in connection with this, is of great importance, nearly 6 per cent of lime. The potash

and soda, and the several acids, are also present in sufficient abundance.

2. In the second—a fertile soil, but one which *cannot dispense with manure*—there is little soluble saline matter, and in the insoluble portion we see that there are mere *traces* only of potash, soda, and the important acids. It contains also only 5 per cent of organic matter, and less than 2 per cent of lime; which smaller proportions, together with the deficiencies above stated, remove this soil from the most *naturally* fertile class to that class which is susceptible, in hands of ordinary skill, of being *brought to*, and *kept in*, a very productive condition.

3. In the fine part of the third soil, we observe that there are many more substances deficient than in No. 2. The organic matter amounts apparently to 4 per cent, and there seems to be nearly half a per cent of lime. But it will be recollected that this soil contains 40 per cent of sand (p. 139); or that in every hundred of soil there are only 60 of the fine matter of which the composition is presented in the table;—or 100 lb. of the native soil contain only 2½ lb. of organic matter and ¼ lb. of lime.

But all these *wants* would not alone condemn the soil to hopeless barrenness, because, in favourable circumstances, they might all be supplied by art. But the oxide of iron amounts to 8 per cent of this fine part of the soil; a proportion of this substance which, in a soil containing so little lime and organic matter, appears, from practical experience, to be incompatible with the healthy growth of cultivated crops. This soil, therefore, requires, not only those substances of which it is destitute, but such other

or black earth of Central Russia, illustrates, in a very striking manner, the fact that the *kind* and *quantity* of the organic matter which a soil contains are scarcely less influential upon its fertility than the mineral constituents to which, in the last section, we principally adverted. This remarkable black soil, "the finest in Russia, whether for the production of wheat or grass," covers an area of upwards of 60,000 square geographical miles, and is said to be everywhere of extreme and of nearly uniform fertility. It nourishes a population of more than twenty millions of souls, and yet annually exports upwards of fifty millions of bushels of corn. This black earth stretches into Hungary, and forms the largest extent of fertile soil possessing common and uniform qualities which is anywhere known to exist. Its origin and chemical composition, therefore, have naturally engaged the attention both of scientific and of practical observers.

Its depth varies from 1 or 2 to 20 feet; when moist, it is jet black; and when dry, of a dark brown. This dark colour, from which it derives its name, is due to the presence of organic, chiefly vegetable, matter, in a peculiar decomposed state, minutely divided and intimately mixed with mineral matter. Of the weight of the dry soil, it forms, in different samples, from 6 to 18 per cent. This vegetable matter is distinguished by two circumstances:

1. That it is in an exceedingly minute state of division, and is intimately mixed with finely-divided mineral matter. The black earth, therefore, forms a comparatively free and open soil, into which the air penetrates, and the roots of plants descend freely.

2. It contains in a state of combination a consider-

able proportion of nitrogen. In different samples this constituent has been found to vary from 2½ (Payen) to 8 per cent (Schmidt) of the weight of the organic matter. Through the action of the air, this nitrogen will favour the production in the soil of nitric acid, ammonia, and other soluble compounds containing nitrogen, which I have already described as propitious to the growth of plants.

But in this black earth the composition of the mineral or inorganic part is also such as to promote fertility. In one of the richest varieties, in which the organic matter amounted to 18 per cent, the mineral matter was found to consist of—

	Per cent.
Potash,	5.81
Soda,	2.31
Lime,	2.60
Magnesia,	0.95
Alumina and oxide of iron, with traces of phosphoric acid,	17.32
Silica, of which 7 or 8 per cent was soluble,	70.94
	99.93

We see in this analysis an abundant supply of those mineral substances which appear to be so necessary to the healthy growth of plants.

The general results of our analytical examination of soils, therefore, are chiefly these :—

a. That a due admixture of organic matter is favourable to the fertility of a soil.

b. That this organic matter will prove the more valuable in proportion to the quantity of nitrogen it holds in combination.

c. That the mineral part of the soil must contain

bonate of lime, the water-cress appears and lines the sides and bottom of its shallow bed, sometimes for many miles from its source.

The Cornish heath (*Erica vagans*) shows itself rarely above any other than the serpentine rocks in which magnesia abounds; the red broom-rape (*Orobanche rubra*), only on trap or basaltic rocks; the *Anemone pulsatilla*, on the dry banks of chalky mounds, as in the neighbourhood of Newmarket; the *Medicago lupulina*, on soils which abound in marl; while the red clover and the vetch delight in the presence of gypsum, and the white clover in that of alkaline matter in the soil.

So the red and white fire-weeds, *Epilobium coloratum* and *Erichtites hieracifolius*, cover with their bright blossoms every open space in the North American woods, over which the fires, so frequent there, have run during the previous year. The ashes of the burned trees and underwood are specially grateful to the seeds of these plants, which in vast quantities lie dormant in the soil.

The clays, too, have their likings. The rest-harrow (*Ononis arvensis*) delights in the weald, the gault, and the plastic clays, but passes by the greensand and chalk soils, by which these clays are separated from each other. The oak, in like manner, characterises the clays of the weald; while the elm flourishes, in preference, on the neighbouring soils of the greensand formation.

Thus also:—

Wheat thrives in clay soils;
Oats and *Clover*, in heavy and compact loams;

Barley and *Turnips*, in open and free loams;

Maize, in an open, free, and even sandy soil;

Rye, in a sandy soil;

Rice, in a stiff, wet, impervious clay;

Beans and *Peas*, in stiff, well-drained clays;

Cocoa-tree, in sandy soils of the coast;

Cotton, in dry, open alluvial (sea islands); dry and porous uplands (chalk-marls of Alabama); hot, dry, and somewhat droughty climate.

Tea-plant, in warm sloping banks, on light dry loams free from clay;

Earth-nut, or *bean*, in light sandy soil;

Cactus tribe, fleshy and water-bearing, in light dry sands, exposed three-fourths of the year to a burning sun;

Oil-palms, in the moist sea sands of the West African coast.

Cinnamon-tree, in an almost pure sand;

The *Hop* "joyeth in a fat and fruitful ground," open, rich, calcareous loam.

The *Date* loves sandy but well-watered places; *e.g.*, near springs in the Great Desert.

Coffee flourishes in rich dry soil and warm situation.

Then, again, plants seem to alternate with each other on the same soil. Burn down a forest of pines in Sweden, and one of birch takes its place *for a while.* The pines after a time again spring up, and ultimately supersede the birch. These changes take place naturally. On the shores of the Rhine are seen ancient forests of oak from two to four centuries old, gradually giving place at present to a natural growth of beech, and others where the pine is succeeding to both. In

the Palatinate, the ancient oak-woods are followed by natural pines; and in the Jura, the Tyrol, and Bohemia, the pine alternates with the beech.

These and other similar differences are believed to depend in great part upon the chemical composition of the soil. The slug may live well upon, and therefore infest, a field almost deficient in lime; the common land-snail will abound at the roots of the hedges only where lime is plentiful, and can easily be obtained for the construction of its shell. So it is with plants. Each grows spontaneously where its wants can be most fully and most easily supplied. If they cannot move from place to place like the living animal, yet their seeds can lie dormant, until either the hand of man or the operation of natural causes produces such a change in their position, in reference to light, heat, &c., as to give them an opportunity of growing—or in the composition and physical qualities of the soil itself, as to fit it for ministering to their most important wants. Change the chemical character of the soil, and the plants change. White clover is a natural plant in all good pasture in Ireland, especially on the great limestone formations. It is a lime-loving, acid-hating plant. Hence lime heavily a sour Irish or Scottish bog or a heathy hillside, and white clover springs up forthwith, as if the seed had been sown. In like manner drainage brings it up by removing the acidity of the soil.

And such changes do naturally come over the soil. The oak, after thriving for long generations on a particular spot, gradually sickens; its entire race dies out, and other races succeed it. Has the operation of natural causes gradually removed from the soil

that which favoured the oak, and introduced or given the predominance to those substances which favour the beech or the pine? On the light soils of the State of New Jersey the peach-tree used to thrive better than anything else, and large sums of money were made from the peach-grounds in that State. But of late years they have almost entirely failed. In Scotland, the Scotch fir has been known at once to die out over an area of 500 or 600 acres—and the forests of larch are now in many localities exhibiting a similar decay. This decay is often, no doubt, owing to the presence of noxious matters in the subsoil, but it is due in some cases also to a natural change in the composition and character of the several soils, which has taken place since the peach, the fir, and the larch trees were first planted upon them.

In the hands of the farmer, the land grows sick of this crop—it becomes tired of that. These facts may be regarded as indications of a change in the chemical composition of the soil. This alteration may proceed slowly and for many years; and the same crops may still grow upon it for a succession of rotations. But at length the change is too great for the plant to bear; it sickens, yields an unhealthy crop, and ultimately refuses altogether to grow.

The plants we raise for food have similar likes and dislikes with those that are naturally produced. On some kinds of food they thrive; fed with others they sicken or die. The soil must therefore be prepared for their special growth.

In an artificial rotation of crops we only follow nature. One kind of crop extracts from the soil a certain quantity of all the inorganic constituents of

plants, but some of these in much larger proportions than others. A second kind of crop carries off, in preference, a large quantity of those substances of which the former had taken little: and thus it is clearly seen, both why an abundant manuring may so alter the composition of the soil as to enable it to grow almost any crop; and why, at the same time, this soil may, in succession, yield more abundant crops, and in greater number, if the kind of plants sown and reaped be so varied as to extract from the soil, one after the other, the several different substances which the manure we have originally added is known to contain.

So with regard to the organic matter which soils contain. That form of organic food which suits one, may not equally favour another species of plant, and thus, at different times, different species may be most suited to the chemical condition of the same field.

It may be that one reason why certain plants are always found in particular soils and situations (as, for example, the Fuci), is, not that they like their surroundings, but because, under other and more favourable conditions, they would be overpowered by other plants. "I saw," says Dean Herbert, "a crocus, a sternbergia, and an ornithogalum growing in contact with each other aloft on the meagre soil of Mount Œnos, but not a seed-pod of the sternbergia could be discovered, and very few of the crocus. In a more fertile soil they would have been choked by some stronger plant, but they would rejoice in a better soil if protected against the oppressor."

Influence of Soils on Cereals.—The varying quality of barley raised in different localities is familiar

to every farmer. On stiff clays, barley may yield a greater produce, but it is of a coarser quality. On light chalky soils it is thin-skinned, rich in colour, and, though light in weight, well adapted for *malting;* while on loamy lands and on sandy marls it assumes a greater plumpness, yet still retains its malting quality.

Similar differences affect the same variety of wheat when grown upon different soils. In a previous chapter it was stated that the quantity of gluten contained in wheat is believed to vary with the climate, and in some degree also with the manure applied to the land; but a similar variation occurs on unlike soils, when manured or otherwise treated in every respect alike. The miller knows by experience the relative qualities of the wheat grown on the several farms in the neighbourhood of his mill, so that even when his eye can detect no difference of quality between two samples, a knowledge of the places where they were grown enables him to decide which of the two it will be most for his interest to buy.

The oat varies in quality likewise with the soil on which it is grown. The meal made from oats grown upon clay land is the best in quality, is the *thriftiest,* keeps the longest, and generally brings the highest price.

Rye also flourishes upon light and sandy soils in general, but when grown upon sandy marls it is found (in Germany) to yield much bran.

Influence of Soils upon Leguminous Plants.—The *pea* and the *bean* are distinguished by similar peculiarities when grown in light and in heavy soils. There are certain spots in the neighbourhood of all large

plants, but some of these in much larger proportions than others. A second kind of crop carries off, in preference, a large quantity of those substances of which the former had taken little: and thus it is clearly seen, both why an abundant manuring may so alter the composition of the soil as to enable it to grow almost any crop; and why, at the same time, this soil may, in succession, yield more abundant crops, and in greater number, if the kind of plants sown and reaped be so varied as to extract from the soil, one after the other, the several different substances which the manure we have originally added is known to contain.

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Influence of Soils upon Leguminous Plants.—The *pea* and the *bean* are distinguished by similar peculiarities when grown in light and in heavy soils. There are certain spots in the neighbourhood of all large

towns, which are known to produce the best boiling peas—such as boil soft and mealy. Thus the gravelly slope of Hopwas hill, near Tamworth, on the Lichfield road, grows the best *sidder* or boiling green peas for the Birmingham market; the vale of Tamworth in general growing only *pig* peas—hard boilers used only for feeding. Lime and gypsum are said by some to impart the boiling quality, while by others exactly the reverse is stated. No doubt the different results are owing to differences in the soils upon which the several experiments were made.

It is a remarkable circumstance, that on the London Corn Exchange the dealers seldom buy British peas without first sending a sample to be boiled; while foreign peas are generally bought without any trial. They are almost invariably boilers. For split-peas, used in making soups and pease-meal, it is obvious that this boiling quality is of great importance.

The explanation of all these differences is, to a certain extent, simple. The relative proportions of gluten and starch in all vegetable juices and seeds are variable. The plant is fitted to flourish, to live in a comparatively healthy manner, and to perform all its natural functions, although the supply of those kinds of food out of which its gluten is formed be greater or less within certain limits; but the boiling, feeding, malting, or distilling qualities of its stems, seeds, or roots, will be materially affected by variations in this supply.

Again, the proportion of gluten seems to be dependent upon the quality of the soil, not only because the nitrogen it contains is chiefly imbibed by the roots of the plant, but because this gluten is always

associated with a certain small quantity of sulphur, phosphorus, and earthy matter, which can only be derived from the soil. Where these elements abound in the neighbourhood of the roots, the plant may produce much gluten—where they are absent, it may not; so that the feeding and other important qualities of the plant depend no less upon the presence of sulphur and phosphorus in the soil, than upon that of any of the so-called organic elements of which its several parts are principally made up.

Still it must be borne in mind that these explanations of the differences observed on the Corn Exchange, and by the miller, are as yet hypothetical. The causes stated *may* produce the effects actually observed, but it has not been proved, by analytical and other experiments, that they really do produce them. Mere age induces changes in the qualities of grain, which the miller values and is willing to pay for.

Influence of Soils upon the Potato.—It is familiarly known to the potato-grower, that clay soils produce waxy, and sandy soils mealy potatoes. But the condition of the land also exercises a material influence both upon their growth and quality. When, for example, potatoes are planted in rich newly-broken-up land, they run up greatly to *shaws* or tops, produce generally few or small tubers, and of bad eating quality, because they seldom ripen before the frost sets in. It has been observed that the quantity of starch is larger in potatoes which are grown upon land long in arable culture than upon such as is newly brought into cultivation or broken up from grass.

Influence of Soil on the Turnip.—That the soil

has an influence on the composition of the turnip crop, has long been believed by the practical man, because of the difference in the taste and feeding properties of the same kind of turnip grown on different fields and farms.

The chemical nature of this difference has been fully investigated by Dr Anderson. His analysis of turnips, grown in the same season and circumstances, upon

a. The heavy alluvial clay of the Carse of Gowrie;

b. The black land which separates the clay from the hill, and there, as in Lincolnshire, skirts the slopes;

c. The hill land, which is a light loam—

showed that the proportion of proteids was almost always greater on the hill-land than on either of the other soils—sometimes *twice as great*. The turnips of the black land were also slightly superior in this respect to those of the clay. This result of analyses fully supports that of practical experience in the feeding of stock.

Influence of Soils on Fruit.—Fruits of all kinds, like our corn and root crops, are affected in flavour and quality by the soil on which they grow. In the Norman orchard, the *gout de terrain* is a recognised quality both in the apple and in the cider. The extended apple and peach culture of North America has led to similar observations; and the peculiar qualities possessed by the wines of neighbouring vineyards are familiar everywhere. There are only three farms situated on the side of a hill which produce the famous Constantia wine. The same grape has been tried in various parts of the Cape colony without suc-

cess. Even a mile from the hill the wine is of a very inferior description. In Europe, on the banks of the Rhine, the Johannisberg is equally well known for the unique qualities of its celebrated wine.

CHAPTER XIII.

THE IMPROVEMENT OF SOILS.

The soil, in its natural condition, is possessed of certain existing and obvious qualities, and of certain other dormant capabilities. How are the existing qualities to be improved,—the dormant capabilities to be awakened?

The General Improvement of Soils.—There are few soils to which something may not still be done in the way of improvement, while by far the greatest breadth of the land, in almost every country, is still susceptible of extensive amelioration. In its present condition, the art of cultivating the land in England generally, differs from nearly all other arts practised among us in this—that he who undertakes it later in life, who brings to it a mind already matured, a good ordinary education, a sound judgment, and a fair share of prudence, who turns to it as a new pursuit, is often seen to take the lead among the agriculturists of the district in which he settles. He comes to the occupation free from the trammels of old customs, old methods, and old prejudices, and hence is free

and thus the plants never experience that genial warmth about their roots which so much favours their rapid growth.

The temperature which a dry soil will attain in the summer-time is often very great. Sir John Herschel observed, that at the Cape of Good Hope the soil attained a temperature of 150° Fahr., when that of the air was only 120°; and Humboldt says that the warmth of the soil between the tropics often rises to from 124° to 136°.

When the land is full of water, it is only after long droughts, and when it has been thoroughly baked by the sun, that it begins to attain the temperature which dry land under the same sun may have reached, day after day, probably for weeks before.

2°. Where too much water is present in the soil, also, that portion of the food of the plant which the soil supplies is so much diluted, that either a much greater quantity of fluid must be taken in by the roots—much more work done by them, that is—or the plant will be scantily nourished. The presence of so much water in the stem and leaves keeps down *their* temperature also—when the sunshine appears, an increased evaporation takes place from their surfaces—a lower natural heat, in consequence, prevails in the interior of the plant, and the chemical changes, on which its growth depends, proceed with less rapidity.

3°. By the removal of the water, the physical properties of the soil, also, are in a remarkable degree improved. Dry pipe-clay can be easily reduced to a fine powder, but it naturally, and of its own accord, runs together when water is poured upon it. So it is

with clays in the field. When wet, they are close, compact, and adhesive, and exclude the air from the roots of the growing plant. But remove the water and they gradually contract, crack in every direction, become thus open, friable, and mellow, more easily and cheaply worked, and pervious to the air in every direction.

4°. The access of this air is essential to the fertility of the soil, and to the healthy growth of most of our cultivated crops. The insertion of drains not only makes room for the air to enter by removing the water, but actually compels the air to penetrate into the under parts of the soil, and renews it at every successive fall of rain. Open such outlets for the water below, and as this water sinks and trickles away, it will *suck* the air after it, and draw it into the pores of the soil wherever itself has been.

Vegetable matter becomes of double value in a soil thus dried and filled with atmospheric air. When drenched with water, this vegetable matter either decomposes very slowly, or produces acid compounds more or less unwholesome to the plant, and even exerts injurious chemical reactions upon the earthy and saline constituents of the soil. In the presence of air, on the contrary, this vegetable matter decomposes rapidly, produces carbonic acid in large quantity, as well as other compounds on which the plant can live, and even renders the inorganic constituents of the soil more fitted to enter the roots, and thus to supply more rapidly what the several parts of the plant require. Hence, on dry land, manures containing organic matter (farmyard manure, &c.) go farther, or are more profitable to the farmer.

5°. Nor is it only stiff and clayey soils to which draining can with advantage be applied. It will be obvious to every one, that when springs rise to the surface in sandy soils, a drain must be made to carry off the water; it will also readily occur, that where a sandy soil rests upon a hard or clayey bottom, drains may likewise be necessary; but it is not unfrequently supposed, that where the subsoil is sand or gravel, thorough draining can seldom be required.

Every one, however, is familiar with the fact that when water is applied to the bottom of a flower-pot full of soil, it will gradually find its way towards the surface, however light the soil may be. So it is in sandy soils or subsoils in the open field—all possess a certain power of sucking up water from beneath (p. 131). If water abound at the depth of a few feet, or if it so abound at certain seasons of the year, *that* water will rise towards the surface; and as the sun's heat dries it off by evaporation, more water will follow to supply its place. This attraction from beneath will always go on when the air is dry and warm, and thus a double evil will ensue—the soil will be kept moist and cold, and instead of a constant circulation *of air downwards*, there will be a constant current *of water upwards.* Thus will the roots, the under soil, and the organic matter it contains, be all deprived of the benefits which the access of the air is fitted to confer, and both the crops and the farmer will suffer in consequence. The remedy for these evils is to be found in an efficient system of drainage.

6°. It is a curious, and apparently a paradoxical observation, that draining often improves soils on which the crops are liable to be *burned up* in seasons of

drought. Yet, upon a little consideration, the fact becomes very intelligible. Let *a b* be the surface of the soil, and *c d* the level at which the water stagnates, or below which there is no outlet by drains or natural openings. The roots will readily penetrate to *c d;* but they will in general refuse to descend farther, because of the unwholesome substances which usually collect in water that is stagnant. Let a dry season come, and their roots, having little depth, the plants will be more or less speedily burnt up. And if water ascend from beneath the line *c d*, to moisten the upper soil, it will bring with it those noxious substances into which the roots have already refused to penetrate, and will cause the crop to droop and wither. But put in a drain, and lower the level of the water to *e f*, and the rains will wash out the noxious water from the subsoil, and the roots will descend deep into it; so that if a drought again come, it may parch the soil above *c d*, as before, without injuring the plants, since now they are watered and fed by the soil beneath, into which the roots have descended.

7°. In many parts of the country, and especially in the red-sandstone districts, the oxide or rust of iron abounds so much in the soil, or in the springs which ascend into it, as gradually to collect in the subsoil, and form a more or less impervious layer or pan, into which the roots cannot penetrate, and through which the surface-water refuses to pass. Such soils are benefited for a time by breaking up the pan where the plough can reach it; but the pan gradually forms again at a greater depth, and the evils again recur.

In such cases, the insertion of drains below the level of the pan is the most certain mode of permanently improving the soil. If the pan be now broken up, the rains sink through into the drains, and gradually wash out of the soil the iron which would otherwise have only sunk to a lower level, and have again formed itself into a solid cake.

8°. It is not less common, even in rich and fertile districts, to see crops of beans, or oats, or barley, come up strong and healthy, and shoot up even to the time of flowering, and then begin to droop and wither, till at last they more or less completely die away. So it is rare in many places to see a second year's clover crop come up strong and healthy. These facts indicate, in general, the presence of noxious matters in the subsoil, which are reached by the roots at an advanced stage of their growth, but into which they cannot penetrate without injury to the plant. The drain calls in the aid of the rains of heaven to wash away these noxious substances from the soil, and of the air to change their nature; and this is the most likely, as well as the cheapest, means by which these evils can be prevented.

9°. Another evil in some countries presents itself to the practical farmer. Saline substances are in certain quantity beneficial, nay, even necessary to the growth of plants. In excess, however, they are injurious, and kill many valuable crops. We have already adverted to the existence of such saline substances in the soil, and to the fact of their rising in incrustations to the surface (p. 83) when droughts prevail.

In some countries, as, for example, in the plains of

Athens, and near the city of Mexico, they come to the surface in such quantity as actually to kill the more tender herbage, and to permit only the stronger plants to grow. In the plains of Athens, when the rainy season ends, a rapid evaporation of water from the surface begins. The water, as it rises from beneath, brings much saline matter with it. This it leaves behind as it ascends in vapour, and thus at length so overloads the surface-soil that tender grass refuses to grow, though the stronger wheat plant thrives well and comes to maturity.

This result could scarcely happen if an outlet beneath were provided for the waters which fall during the rainy season. These would wash out and carry away the excess of saline matter which exists in the under soil, and would thus, when the dry weather comes, prevent it from ascending in such quantities as to injure the more tender herbage.

It may be objected to this suggestion, that drains in such countries would render more dry a soil already too much parched by the hot suns of summer. It is doubtful, however, if this would really be the case. Deep drains, as in the case above explained (6°), would enable the roots to penetrate deeper, and would thus render them more independent of the moisture of the surface-soil.

10°. On this subject we shall add one important practical remark, which will readily suggest itself to the geologist who has studied the action of air and water on the various clay-beds that occur here and there, as members of the series of stratified rocks. There are no clays which do not gradually soften under the united influence of air, of frost, and of

running water. It is false economy, therefore, to lay down tiles of the common horse-shoe form without soles, however hard and stiff the clay subsoil may appear to be. In the course of ten or fifteen years, the stiffest clays will *generally* soften so much as to allow the tile to sink to some extent—and many very much sooner. The passage for the water is thus gradually narrowed; and when the tile has sunk a couple of inches, the whole may have to be taken up. Thousands of miles of drains have been thus laid down, both in the low country of Scotland and in the southern counties of England, which have now become nearly useless. The extending use of the pipe-tile will, it is to be hoped, gradually lessen the chances of pecuniary loss which the above practice involves.

The *economical* advantages of draining in such soils as we possess are chiefly these :—

1. Stiff soils are more easily and more cheaply worked.

2. Lime and manures have more effect, and go farther.

3. Seed-time and harvest are earlier and more sure.

4. Larger crops are reaped, and of better quality.

5. Nutritive grasses spring up where inferior grasses formerly grew.

6. Valuable crops of wheat and turnips are made to grow where scanty crops of oats were formerly the chief return.

7. Naked fallows are rendered less necessary, and more profitable rotations can be introduced.

8. The climate is improved, and rendered not only more suited to the growth of crops, but more favourable to the health of man and other animals.

9. The soil is actually enriched by what the rains bring down.

10. Air is sucked down into the subsoil.

Proper Depth to which Drains ought to be dug.—Much has lately been written in regard to the depth to which drains ought to be dug in a system of thorough drainage. It is difficult, perhaps impossible, to establish any empirical or general rule upon this subject; but there are certain indisputable points which will serve to guide the intelligent farmer in most cases which are likely to occur.

1°. It is acknowledged, as a general rule, to be of great importance that the soil should be deepened—that it should be opened up, for the descent of the roots, to the greatest depth to which it can be economically done. Now, by the use of the subsoil-plough or the fork, the soil can be stirred to a depth of from 22 to 24 inches. The tile—or the top of the drain, if made of stones—should be at least three inches clear of this disturbance of the upper soil; and as most tiles will occupy at least 3 inches, we reach 30 inches as the minimum depth of a tile drain, and about 3 feet as the minimum depth of a stone drain, in which the layer of stones has a depth of not more than 9 inches.

2°. Where the outfall is bad, and a depth of 30 or 36 inches cannot be obtained, the drains should be as deep as they can be made to run and deliver water.

3°. The roots of our corn and other crops will, in favourable circumstances, descend to a depth of 4 or 5 feet. They do so in quest of food, and the crop above ground is usually the more luxuriant the deeper

the roots are enabled to penetrate. It is therefore theoretically desirable to dry the soil to a greater depth even than 3 feet, where it can be done without too great an outlay of money.

4°. The question of economy, therefore, is one of great importance in this inquiry. In some places it costs as much to dig out the fourth or lowest foot as is paid for the upper three; and this additional cost is, in many localities, a valid reason for limiting the depth to 30 inches, or 3 feet.

5°. But the question of economy ought to be disregarded, and deeper drains dug where springs occur beneath, or where, by going a foot deeper, a bed or layer is reached in which much water is present The reason of this is, that though water may not ris from this wet layer in such quantity as actually run along the drains, yet it may do so in sufficiils abundance to keep the subsoil moist and cold, thus to retard the development of the crops that:ed. on its surface. go

The above circumstances appear sufficient to the practical man in most cases that will presenture. selves to him. No uniform depth can be fixality. it must be modified by local circumstances. rasses

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more deeply and escape more rapidly from the soil. It may be interesting to specify briefly the benefits which are known to follow from this descent of the rain through the soil.

1°. *It causes the air to be renewed.*—It is believed that the admission of frequently-renewed supplies of air into the soil is favourable to its fertility. This the descent of the rain promotes. When it falls upon the soil it makes its way into the pores and fissures, expelling of course the air which previously filled them. When the rain ceases, the water runs off by the drains; and as it leaves the pores of the soil empty above it, the air follows, and fills with a renewed supply the numerous cavities from which the descent of the rain had driven it. Where land remains full of water, no such renewal of air can take place.

or 2°. *It warms the under soil.*—As the rain falls
22 ough the air it acquires the temperature of the
if m: sphere. If this be higher than that of the sur-
clear soil, the latter is warmed by it; and if the rains
most pious, and sink easily into the subsoil, they will
inches this warmth with them to the depth of the drains.
about 3 under soil in well-drained land is not only
in which because the evaporation is less, but because
than 9 is in the summer season actually bring down
2°. W from the atmosphere to add to its natural
or 36 in
be as de*equalises the temperature of the soil during the*
water. *owth.*—The sun beats upon the surface
3°. The , and gradually warms it. Yet, even in
favourable is direct heat descends only a few inches
5 feet. The surface. But when rain falls upon the
above gro ace, and finds an easy descent, as it does in

open soils, it becomes itself warmer, and carries its heat down to the under soil. Then the roots of plants are warmed, and general growth is stimulated.

It has been proved, by experiments with the thermometer, that the under as well as the upper soil is warmer in drained than in undrained land ; and the above are some of the ways by which heat seems to be actually added to soils that have been thoroughly drained.

4°. *It carries down soluble substances to the roots of plants.*—When rain falls upon heavy undrained land, or upon any land into which it does not readily sink, it runs over the surface, dissolves any soluble matter it may meet with, and carries it into the nearest ditch or brook. Rain thus robs and impoverishes such land.

But let it sink where it falls, then whatever it dissolves it will carry downwards to the roots—it will distribute uniformly the saline matters which have a natural tendency to rise to the surface, and it will thus promote growth by bringing food everywhere within the reach of plants.

5°. *It washes noxious matters from the under soil.*—In the subsoil, beyond the reach of the air, substances are apt to collect, especially in red-coloured soils, which are injurious to the roots of plants. These the descent of the rains alters in part and makes wholesome, and in part washes out. The plough may then safely be trusted deeper, and the roots of plants may descend in search of food where they would previously have been destroyed.

It is true that, when heavy rains fall, they will also wash out of the soil and carry into the drains sub-

stances which it would be useful to retain. Upon this fact some have laid unnecessary stress, and have adduced it as an argument against thorough drainage. But if we balance the constant benefit against the occasional evil, I am satisfied, as experience indeed has shown, that the former will greatly preponderate.

6°. *It brings down fertilising substances from the air.*—Besides, the rains never descend empty-handed. They constantly bear with them gifts, not only of moisture to the parched herbage, but of organic and saline food, by which its growth is promoted. Ammonia and nitric acid, together with the many exhalations which are daily rising from the earth's surface, come down in the rains; common salt, gypsum, and other saline substances derived from the sea, are rarely wanting; and thus, the constant descent from the heavens may well be supposed to counterbalance the occasional washings from the earth.

7°. *Much of the rain is evaporated.*—And lastly, in answer to this objection, it is of importance to state, that in our climate a very large proportion of the rain that falls does not sink through the soil, even where there are drains beneath, but rises again into the air in the form of watery vapour. Experiments in Manchester have shown, that of 31 inches of rain which fall there in a year, 24 are evaporated; while in Yorkshire, of 24½ inches of rain which fall, only 5 inches run off through pipes laid at a depth of 2 feet 9 inches, the rest being evaporated. There is little cause, therefore, for the fear expressed by some, that the draining of the land will cause the fertility in any perceptible degree to diminish in consequence of the washing of the descending rains. They may,

as we have said, improve the subsoil by washing hurtful substances out of it; but, in general, the soil will have extracted from the water which filters through it all the valuable matter it holds in solution before it has reached the depth of a 3-feet drain.

The greater the number of trees in a country, the greater, other conditions being equal, is its rainfall. In France the extent of forests and woods in 1750 was estimated to cover 40,000,000 of English acres; the area under timber is now reduced by one-half. This has led to a decrease in the annual rainfall, which, according to some authorities, is injurious to the agriculture of the country. Egypt was once a rainless country, but now, by the planting of millions of trees in it, rain descends regularly every winter.

CHAPTER XIV.

IMPROVEMENT OF SOILS BY TILLAGE AND MIXING.

After the land has been laid dry by drains, other mechanical modes of improvement can be employed with advantage. Even the ordinary methods of mechanical culture become more useful, and the benefits which in favourable circumstances are derived from turning up the soil are greater and more manifest. These facts will appear by a brief consideration of the effects produced by ploughing to various depths, and the causes from which they arise.

Use of the Subsoil-Plough.—The subsoil-plough is an auxiliary to the drain—it stirs and opens the under soil without mixing it with the upper or immediately active soil. Though there are few subsoils through which the water will not at length make its way, yet there are some so stiff, either naturally or from long consolidation, that the good effect of a well-arranged line of drains is lessened by the slowness with which they allow the superfluous water to pass through them. In such cases, the use of the subsoil-plough is most advantageous in loosening the under layers of soil, and in allowing the water to find a ready escape downwards to either side, until it reaches the drains.

It is well known that if a piece of stiff clay be cut into the shape of a brick, and then allowed to dry, it will contract and harden—it will form an air-dried brick, almost impervious to any kind of air. Wet it again, it will swell and become still more impervious. Cut up *while wet*, it will only be divided into so many pieces, each of which will harden when dry, or the whole of which will again attach themselves and stick together if exposed to pressure while they are still wet. But tear it asunder *when dry*, and it will fall into many pieces, will more or less crumble, and will readily admit the air into its inner parts. So it is with a clay subsoil.

After the land is provided with drains, the subsoil being very retentive, the subsoil-plough is used to open it up—to let out the water and let in the air. If this is not done, the stiff under-clay will contract and bake as it dries, but it will neither sufficiently admit the air, nor open so free a passage for the

roots. Let this operation, however, be performed when the clay is still too wet, a good effect will follow in the first instance; but after a while the cut clay will again cohere, and the farmer will pronounce subsoiling to be a useless expense *on his land.* Defer the use of the subsoil-plough till the clay is dry—it will then *tear* and *break* instead of *cutting* it, and its openness will remain. Once give the air free access, and, after a time, it so modifies the drained clay that it no longer has an equal tendency to cohere.

Mr Smith of Deanston very judiciously recommended that the subsoil-plough should never be used till at least a year after the land has been thoroughly drained. This in many cases will be a sufficient safeguard—will allow a sufficient time for the clay to dry: in other cases, two years may not be too much. But this precaution has by some been neglected; and, subsoiling being with them a failure, they have sought, in some supposed chemical or other quality of their soil, for the cause of a want of success which is to be found in their own neglect of a most necessary precaution. Let not the practical man be too *hasty* in desiring to attain those benefits which attend the adoption of improved modes of culture; let him give every method a fair trial; and above all, let him make his trial in the way and with the precautions recommended by the author of the method, before he pronounce its condemnation.

The Profit of Subsoiling. Use of the Fork.—The benefits of subsoil-ploughing are well illustrated by the following numerical results observed on two farms in the neighbourhood of Penicuik, a few miles from Edinburgh.

1°. Mr Wilson of Eastfield, Penicuik, made an experiment, after thorough drainage, upon two portions of land under each of three crops, and found the effects in the first year after subsoil-ploughing, compared with ordinary ploughing, to be as follows:—

	Turnips.	Barley.		Potatoes.
		Grain.	Straw.	
	tons. cwt.	qrs.	cwt.	tons. cwt.
Ploughed to 8 inches,	20 7	7¼	28	6 14¾
Subsoiled to 15 inches,	26 17	8⅜	36½	7 9½
Difference,	6 10	⅞	8½	15¾

From this table, the effect of subsoiling to a depth of 15, above that of ploughing to a depth of 8 inches, appears to have been to increase the turnip crop by 6½ tons, the potatoes by 15 cwt., and the barley by 7 bushels of grain and 8 cwt. of straw.

2°. Mr Maclean of Braidwood, near Penicuik, made a similar experiment with turnips and barley, with the following results:—

	Turnips.	Barley.	
		Grain.	Straw.
	tons. cwt.	qrs.	stones.
Ploughed 8 inches deep, .	19 15	6¾	168½
Subsoiled to 15 inches, . .	23 17	7⅜	206½
Difference, . .	4 2	⅝	38

The turnip crop in this experiment was increased

4 tons, and the barley crop by ⅝th quarter of grain, and 38 stones of straw.

It has been observed, also, that the effects of the subsoiling do not cease with the first crop. In one case, in which an accurate account of the produce was kept, the profit was estimated at 6s. an acre, *for five successive years after the operation.* There is reason, therefore, to anticipate general good from the careful introduction of this practice; though it is exceedingly desirable, at the same time, that the causes of its failure, wherever it is found to fail, should be rigorously investigated.

The use of the fork, instead of the subsoil-plough, has lately been recommended as a more efficient, and even a more economical method of opening up the under soil. The upper soil of 9 to 12 inches is thrown forward with a spade, and the under soil, to a depth of 15 inches further, is stirred and turned over with a three-pronged fork. I have seen it in operation; and it certainly does appear to loosen and open up the under soil more effectually than the subsoil-plough can do, and to a depth which few subsoil-ploughs are yet able to reach.

How Deep Ploughing improves the Soil.—*Deep ploughing*, like subsoiling, aids the effect of the drains, and so far—where it goes nearly as deep—even more completely effects the same object. But independently of this, it has other uses and merits, and, where it has been successfully applied, has improved the land by the operation of other causes.

Subsoiling only lets out the water, and allows access to the air and rains, and a free passage to the roots. Deep ploughing, in addition to these, brings new

earth to the surface, forms thus a deeper active soil, and more or less alters both its physical qualities and its chemical composition.

If the plough be made to bring up two inches of clay or sand, it will stiffen or loosen the soil, as the case may be; or it may affect its colour or density. It is clear and simple enough, therefore, that by deep ploughing, the physical properties of the soil may be altered.

But there are certain substances contained in every soil, whether in pasture or under the plough, which gradually make their way down towards the subsoil. They sink till they reach at last that point beyond which the plough does not usually penetrate. Every farmer knows that lime thus sinks. In peaty soils top-dressed with clay, as is done in Lincolnshire, the clay thus sinks. In sandy soils, also, which have been clayed, the clay sinks: and in all these cases, we believe, the sinking takes place more rapidly when the land is laid down to grass. Where soils are marled, the marl sinks; and the rains, in like manner, gradually wash out that which gives their fertilising virtue to the large doses of chalk which in some districts are spread upon the land, and render necessary a new application to renovate its productive powers.

If this be the case with earthy substances such as those now mentioned, which are, for the most part, insoluble in water, it will be readily believed that those saline ingredients of the soil which are easily soluble, will be still sooner washed out of the upper, and conveyed to the under, soil. Thus the subsoil may gradually become rich in those substances of which the surface-soil has been robbed by the rains.

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Bring up a portion of this subsoil by deep ploughing, and you restore to the surface-soil a part of what it has been gradually losing—you bring up what may probably render it more fruitful than before. Such is an outline of the reasons in favour of deep ploughing.

In Germany, theory has pointed out the growing of an occasional *deep-rooted* crop in light soils to effect the same end. The deep roots bring up again to the surface the substances which had naturally sunk.

But suppose the land to have originally contained something noxious to vegetation, which in process of time has been washed down into the subsoil, then to bring this again to the surface would be materially to injure the land. This also is true, and a sound discretion must be employed, in judging when and where such evil effects are likely to follow.

Such cases, however, are more rare than many suppose. There are few subsoils which, *after a year's draining*, a full and fair exposure to the winter's frost will not in a great degree deprive of all their noxious qualities, and render fit to ameliorate the general surface of the poorer lands. If the reader doubt this fact, let him visit Yester, and give a calm consideration to the effects produced by deep ploughing on the home farm of the Marquis of Tweeddale. Let him also study the practice of deep ploughing as it is followed by the Jersey farmers, and he will be still further persuaded of the value of deep ploughing, in some localities at least.

In many cases the farmer fears, as he does in some parts of the county of Durham, to bring up a single inch of the yellow clay that lies beneath his surface-soil. In the first inch lodges, among other sub-

stances, the iron worn from his plough, which, in some soils, and after a lapse of years, amounts to a considerable quantity. Till it is exposed to the air, this iron is hurtful to vegetation; and one of the benefits of a winter's exposure of such subsoils to the air arises from the effect produced upon the iron they contain.

It is the want of drainage, however, and of the free access of air, that most frequently renders subsoils for a time injurious to vegetation. Let the lands be well drained—let the subsoils be washed for a few years by the rain-water passing through them—and there are few of those which are clayey in their nature that may not ultimately be brought to the surface, not only with safety, but with advantage to the upper soil.

TRENCHING with the spade more fully and effectually performs what the trench-plough is intended to do. The spade more completely turns over the soil than the plough does; and in the hands of an industrious labourer, many think it the more economical instrument of the two.

It is chiefly because the spade or the fork divides and separates the soil more completely, or to a greater depth, that larger crops have been obtained in many districts by the introduction of spade-husbandry than by the ordinary mode of culture with the plough. But all these benefits, which a thorough working of the soil is fitted to confer, are only fully realised where the land is naturally dry, or by artificial drainage has been freed from superfluous water.

Chemical Effects of Ploughing.—Other benefits, again, attend upon the ordinary ploughings, hoeings, and working of the land. Its parts are more minutely

divided—the air gets access to every particle—it is rendered lighter, more open, and more permeable to the roots. The vegetable matter it contains decomposes more rapidly by a constant turning of the soil, so that wherever the fibres of the roots penetrate, they find organic food provided for them, and an abundant supply of the oxygen of the atmosphere to aid in preparing it. The production of ammonia and of nitric acid also, and the absorption of these and of watery vapour from the air, take place to a greater extent the finer the soil is pulverised, and the more it has been exposed to the action of the atmosphere. All soils contain, likewise, an admixture of fragments of those minerals of which the granitic and trap rocks are composed, which, by their decay, yield new supplies of inorganic food to the growing plant. The more frequently they are exposed to the air, the more rapidly do these fragments crumble away and decompose. The general advantage, indeed, to be derived from the constant working of the soil, may be inferred from the fact, that Tull reaped twelve successive crops of wheat from the same land by the repeated use of the plough and the horse-hoe. There are few soils so stubborn as not to show themselves grateful in proportion to the amount of this kind of labour that may be bestowed upon them.

Improvement of Soils by Mixing.—It has been already shown that the physical properties of the soil have an important influence upon its average fertility. The admixture of pure sand with clay soils produces an alteration which is often beneficial, and which is almost wholly physical. The sand opens the pores of the clay, and makes it more permeable to the air.

The admixture of clay with sandy or peaty soils, however, produces both a physical and a chemical alteration. The clay not only consolidates and gives body to the sand or peat, but it also mixes with them certain earthy and saline substances, useful or necessary to the plant, which neither the sand nor peat might originally contain in sufficient abundance. It thus alters its chemical composition, and fits it for nourishing new races of plants.

Such is the case also with admixtures of marl, of shell-sand, and of lime. They slightly consolidate the sands and open the clays, and thus improve the mechanical texture of both kinds of soil; but their main operation is chemical; and the almost universal benefit they produce depends mainly upon the new chemical element they introduce into the soil.

The cost of applying clay to light land is given as follows in the second volume of the 'Journal of the Royal Agricultural Society of England':—

Digging and spreading 150 yards of clay, at 4½d. per yard, ...	£2	16	3
4 horses, at 2s. 6d. each per day for 4 days,	2	0	0
Drivers, ...	0	10	0
Various expenses, including allowance for wear and tear, ...	0	3	0
	£5	9	3

It is stated that the operation proved a financial success. It should, however, be observed, that it will hardly pay in those days of high-priced labour to transport clay from a long distance for the purpose of mixing soils. In the drainage of Whittlesea Mere, a portion of adjacent bog-land was reclaimed by spreading over it a layer of soil, on the average

5 inches deep. The soil was taken from the bed of the Mere, a distance of two miles. The cost of claying to the depth of 4 inches proved to be between £15 and £16 per acre, and £18 when the layer was 6 inches deep. The bog, which previously was worthless, was after its reclamation let at 30s. per acre; so that the operation, costly as it proved, was a remunerative one. Mr W. Wells states ('Journal of the Royal Agricultural Society of England,' vol. vi. second series, 1870) that bog-land reclaimed by mixing with clay should not too early be brought under a system of crop rotation. He recommends coleseed to be sown early in July, and to feed sheep on the crop, giving them in addition oilcake. In the following winter the land should be ploughed, and in the spring oats sown, not too early. In May a mixture of red and white clover, timothy, parsley, pacey, trifolium, and Italian ryegrass should be sown and trodden in; but they should not be kept longer than a year.

It is a matter of almost universal remark that in our climate soils are fertile—clayey or loamy soils, that is — only when they contain an appreciable quantity of lime. In whatever way it acts, therefore, the mixing of lime in any of the forms above mentioned, with a soil in which little or no lime exists, is one of the surest practical methods of bringing it nearer in composition to those soils from which the largest returns of agricultural produce are usually obtained.

CHAPTER XV.

IMPROVEMENT OF SOILS BY THE AGENCY OF VEGETATION.

There are certain modes of improving the soil, which, though involving only simple mechanical operations on the part of the improver, produce their effects through the agency of refined scientific causes. Such are the improvements produced by planting and laying down to grass. These shall be briefly considered in the present chapter.

Improvement of the Soil by Planting.—It has been observed that lands which are unfit for arable culture, and which yield only a trifling rent as natural pasture, are yet in many cases capable of growing profitable plantations, and of being greatly increased in permanent value by the prolonged growth of wood. Not only, however, do all trees not thrive alike on the same soil, but all do not improve the soil on which they grow in an equal degree.

Under the Scotch fir, for example, the pasture which springs up after a lapse of years is not worth 6d. more per acre than before the land was planted. Under the beech and spruce it is worth even less than before, though the spruce affords excellent shelter; under the ash it gradually acquires an increased value of 2s. or 3s. per acre. In oak copses it becomes worth 5s. or 6s., but only during the last eight years (of the twenty-four) before the oak copse is cut down. But under the larch, after the first

thirty years, when the thinnings are all cut, land not worth originally more than 1s. per acre becomes worth 8s. to 10s. per acre for permanent pasture.

1. The main cause of this improvement is to be found in the nature of the soil, which gradually accumulates beneath the trees by the shedding of their leaves. The shelter from the sun and rain which the foliage affords prevents the vegetable matter which falls from being so speedily decomposed, or from being so much washed away, and thus permits it to collect in larger quantities in a given time than where no such cover exists. The more complete the shelter, therefore, the more rapid will the accumulation of soil be, in so far as it depends upon this cause.

2. But the quantities of leaves which annually fall, as well as the degree of rapidity with which, under ordinary circumstances, they undergo decay, have also much influence upon the extent to which the soil is capable of being improved by any given species of tree. The broad leaves of the beech and oak decay more quickly than the needle-shaped leaves of the pine tribes, and this circumstance may assist in rendering the larch more valuable as a permanent improver.

3. We should expect, likewise, that the quantity and quality of the inorganic matter contained in the leaves (p. 268)—brought up year by year from the roots, and strewed afterwards uniformly over the surface where the leaves are shed — would materially affect the value of the soil they form. The dry leaves of the oak, for example, contain about 5 per cent of saline and earthy matter, while those of the Scotch

fir contain less than 2 per cent; so that, supposing the actual weight of leaves which falls from each kind of tree to be equal, we should expect a greater depth of soil to be formed in the same time by the oak than by the Scotch fir. The leaves of the larch in the dry state contain from 5 to 6 per cent of saline matter, so that they may enrich the surface on which they fall in at least an equal degree with those of the oak. Much, however, depends upon the annual weight of leaves shed by each kind of tree, in regard to which we possess no precise information.

The improvement of the land, therefore, by the planting of trees, depends in part upon the quantity of *organic* food which the trees can extract from the air, and afterwards drop in the form of leaves upon the soil, and in part upon the kind and quantity of *inorganic* matter which the roots can bring up from beneath, and in like manner strew upon the surface. The quantity and quality of the latter will, in a great measure, determine the kind of grasses which will spring up, and the consequent value of the pasture in the feeding of stock. In the larch forests of the Duke of Athole the most abundant grasses that spring up are said to be the Holcus mollis and the Holcus lanatus (the *meadow* and the *creeping* soft grasses).

The action of a tree, therefore, in improving the soil, is twofold:—

1°. It causes vegetable matter to accumulate on the surface; and,

2°. It brings up from beneath certain substances which are of vital importance to the growth of plants, but in which the upper soil may have been deficient.

In a previous chapter we have described the *black*

earth of Central Russia, which presents probably the most remarkable example now existing of the fertilising effect of a long-continued growth of trees. The cotton soil of Central and Southern Hindostan owes its richness to a similar cause.

Improvement of Soils by Meadowing and Pasturing them.—On this subject, two facts seem to be pretty generally acknowledged.

First, That land laid down to artificial grasses for one, two, three, or more years, is in some degree rested or recruited, and is fitted for the better production of after-crops of corn. Letting it lie a year or two longer in grass, therefore, is one of the received modes of bringing back to a sound condition a soil that has been exhausted by injudicious cropping.

Second, That land thus laid down with artificial grasses diminishes in value again after two, three, or five years—more or less—and only by slow degrees acquires a thick sward of rich, nourishing, natural herbage. Hence the opinion that grass-land improves in quality the longer it is permitted to lie—the unwillingness to plough up old pasture—and the comparatively high rents which, in some parts of the country, old grass-land is known to yield.

Granting that grass-land does thus *generally* increase in value, three important facts must be borne in mind before we attempt to assign the cause of this improvement, or the circumstances under which it is likely to take place for the longest time and to the greatest extent.

1. The value of the grass in any given spot may increase for an indefinite period, but it will never improve beyond a certain extent—it will necessarily

be limited, as all other crops are, by the quality of the land. Hence the mere laying down to grass will not make *all* land *good*, however long it may lie. The extensive commons, heaths, and wastes, which have been in grass from the most remote times, are evidence of this. They have, in most cases, yielded so poor a natural herbage as to have been considered unworthy of being enclosed as permanent pasture.

2. Some grass-lands will retain the good condition they thus slowly acquire for a very long period, and *without manuring*—in the same way, and upon nearly the same principle, that some rich corn-lands have yielded successive crops for 100 years without manure. The rich grass-lands of England, and especially of Ireland, many of which have been in pasture from time immemorial, without receiving any known return for all they have yielded, are illustrations of this fact.

3. But others, if grazed, cropped with sheep, or cut for hay, will gradually deteriorate, unless some proper supply of manure be given to them—which required supply must vary with the nature of the soil, with the kind of stock fed upon it, and with the kind of treatment to which it has been subjected.

How Grasses improve Soils.—In regard to the acknowledged benefit of laying down to grass, then, two points require consideration.

1°. What form does it assume, and how is it effected?

The improvement takes place by the gradual accumulation of a dark-brown soil rich in vegetable matter, which soil thickens or deepens in proportion to the time during which it is allowed to lie in grass. It is a law of nature, that this accumulation takes

place more rapidly in the temperate than in tropical climates, and it would appear as if the consequent darkening of the soil were intended, among other purposes, to enable it to absorb more of the sun's warmth, and thus more speedily to bring forward vegetation where the average temperature is low and the summers comparatively short.

If the soil be very light and sandy, the thickening of the vegetable matter is sooner arrested; if it be moderately heavy land, the improvement continues for a longer period; and some of the heaviest clays in England are known to bear the richest permanent pastures.

The soils formed on the surface of all our rich old pasture-lands thus come to possess a remarkable degree of uniformity—both in physical character and in chemical composition. This uniformity they gradually *acquire*, even upon the stiff clays of the lias and Oxford clay, which originally, no doubt, have been left to natural pasture—as many clay-lands still are—from the difficulty and expense of submitting them to arable culture.

2°. How do they acquire this new character, and why is it the work of so much time?

a. When the young grass throws up its leaves into the air, from which it derives so much of its nourishment, it throws down its roots into the soil in quest of food of another kind. The leaves may be mown or cropped by animals, and carried off the field; but the roots remain in the soil, and, as they die, gradually fill its upper part with vegetable matter. On an average, the *annual* production of roots on old grass-land is equal to one-third or one-fourth of the weight

of hay carried off—though no doubt it varies much, both with the kind of grass and with the kind of soil. When wheat is cut down, the quantity of straw left in the field, in the form of stubble and roots, is sometimes greater than the quantity carried off in the sheaf. Upon a grass-field two or three tons of hay may be reaped from an acre, and therefore, from half a ton to a ton of dry roots is annually produced and left in the soil. If anything like this weight of roots dies every year, in land kept in pasture, we can readily understand how the vegetable matter in the soil should gradually accumulate. In arable land this accumulation is prevented by the constant turning up of the soil, by which the fibrous roots, being exposed to the free access of air and moisture, are made to undergo a more rapid decomposition.

b. But the roots and leaves of the grasses contain earthy and saline matters also. Dry hay leaves from an eighth to a tenth part of its weight of ash when burned. Along with the dead vegetable matter of the soil, this inorganic matter also accumulates in the form of an exceedingly fine earthy powder; hence one cause of the universal fineness of the surface-mould of old grass-fields. The earthy portion of this inorganic matter consists chiefly of silica, lime, and magnesia, with scarcely a trace of alumina; so that, even on the stiffest clays, a surface-soil may be ultimately formed, in which the quantity of alumina—the substance of clay—is comparatively small.

c. There are still other agencies at work, by which the surface of stiff soils is made to undergo a change. As the roots of the grasses penetrate into the clay, they more or less open up a way into it for the rains.

Now the rains in nearly all lands, when they have a passage downwards, have a tendency to carry the clay along with them. They do so, it has been observed, on sandy and peaty soils, and more quickly when these soils are laid down to grass. Hence the mechanical action of the rains—slowly in many localities, yet surely—has a tendency to lighten the surface-soil, by removing a portion of its clay. They constitute one of those natural agencies by which, as elsewhere explained, important differences are ultimately established, almost everywhere, between the surface crop-bearing soil and the subsoil on which it rests.

d. But further, the heats of summer and the frosts of winter aid this slow alteration. In the extremes of heat and of cold, the soil contracts more than the roots of the grasses do; and similar, though less visible, differences take place during the striking changes of temperature which are experienced in our climate in the different parts of almost every day. When the rain falls, also, on the parched field, or when a thaw comes on in winter, the earth expands, while the roots of the grasses remain nearly fixed; hence the soil rises up among the leaves, mixes with the vegetable matter, and thus assists in the slow accumulation of a rich vegetable mould.

The reader may have witnessed in winter how, on a field or by a wayside, the earth rises above the stones, and appears inclined to cover them; he may even have seen, in a deserted and undisturbed highway, the stones gradually sinking and disappearing altogether, when the repetition of this alternate contraction and expansion of the soil for a succession of

winters has increased, in a great degree, the effects which follow from a single accession of frosty weather.

So it is in the fields. And if a person skilled in the soils of a given district can make a guess at the time when a given field was laid down to grass, by the depth at which the stones are found beneath the surface, it is partly because this loosening and expansion of the soil, while the stones remain fixed, tends to throw the latter down by an almost imperceptible quantity every year that passes.

e. Such movements as these act in opening up the surface-soil, in mixing it with the decaying vegetable matter, and in allowing the slow action of the rains gradually to give its earthy portion a lighter character. But with these, among other causes, conspires also the action of living animals. Few persons have followed the plough without occasionally observing the vast quantities of earth-worms with which some fields seem to be filled. On a close-shaven lawn, many have noticed the frequent little heaps of earth which these worms during the night have thrown out upon the grass. These and other minute animals are continually at work, especially beneath an undisturbed and grassy sward—and they nightly bring up from a considerable depth, and discharge on the surface, their burden of fine fertilising loamy earth. Each of these burdens is an actual gain to the rich surface-soil; and who can doubt that, in the lapse of years, the unseen and unappreciated labours of these insect tribes must both materially improve its quality and increase its depth?

f. In most localities, also, the winds may be mentioned among the natural agencies by which the soil

on grass-lands is slowly improved. They seldom sweep over any considerable extent of arable land without bearing with them particles of dust and sand, which they drop in sheltered places, or leave behind them when sifted by the blades of grass, or by the leaves of an extensive forest. In hot summers, in dry springs, and even in winter, when the snow is drifting, the ploughed lands and dusty roads are more or less bared of their lighter particles of soil, which are strewed by the winds as a natural top-dressing over the neighbouring untilled fields.

In some countries the agency of the winds is more conspicuous than among ourselves. Thus, on the banks of the Kuruman and Orange rivers in South Africa, the winds blow during the spring months—August to November in that climate—from the Kulagare desert, bearing with them light particles of dust, which make the air seem as if dense with smoke, and which are so exquisitely fine as to penetrate through seams and cracks which are almost impervious to water.* Forest-trees and waving grass sift this thick air, and enrich the soils on which they grow by the earthy particles they arrest.

In countries where active volcanoes exist, these also exercise an appreciable influence of a similar kind upon the surface-soil. Showers of dust and ashes are sprinkled widely over the land, by which its natural agricultural capabilities are materially interfered with. Vesuvius is said, in this way, to scatter its ashes over the adjoining country, so as, on an average, to destroy the crop every eighth year. But to this circumstance the remarkable general

* Moffat's Missionary Labours, p. 333.

richness of the soil is ascribed—(Mohl.) So does good arise from seeming evil.

There are natural causes, then, which we *know* to be at work, that are sufficient to account for nearly all the facts that have been observed in regard to the effect of laying land down to grass. Stiff clays will gradually become lighter on the surface, and, if the subsoil be rich in all the kinds of inorganic food which the grasses require, will go on improving for an indefinite period without the aid of manure. Let them, however, be deficient in, or let them gradually become exhausted of, any one kind of this food, and the grass-lands will either gradually deteriorate after they have reached a certain degree of excellence, or they must be supplied with that one ingredient, that one kind of manure of which they stand in need. It is doubtful if any pasture-lands are so naturally rich as to bear to be cropped for centuries without the addition of manure, and at the same time without deterioration. Where they appear to be so, they probably receive from springs, from sea-drift, or from some other unobserved source, those perennial supplies which reason pronounces to be indispensable.

On soils that are light, again—which naturally contain little clay—the grasses will thrive more rapidly, and a thick sward will be sooner formed, but the tendency of the rains to wash out the clay may prevent them from ever attaining that luxuriance which is observed upon the old pastures of the clay-lands.

On undrained heaths and commons, and generally on any soil which is deficient in some fertilising element, neither abundant herbage, nor good crops of any other kind, can be expected to flourish. Laying

such lands down, or permitting them to remain, in grass, may prepare them for by-and-by yielding one or two average crops of corn, but cannot be expected *alone* to convert them into valuable pasture.

Finally, plough up the old pastures on the surface of which this light and most favourable soil has been long accumulating, and the heavy soil from beneath will be again mixed up with it, the vegetable matter will disappear rapidly by exposure to the air during the frequent ploughings; and, if again laid down to grass, the slow changes of many years must again be begun through the agency of the same natural causes, before it become capable a second time of bearing the same rich herbage it was known to nourish while it lay undisturbed.

Many have supposed that, by sowing down with the *natural* grasses, a thick and permanent sward may at once be obtained; and on light loamy land, rich in vegetable matters, this method may, to a certain extent, succeed; but on heavy land in which stiff clay abounds and vegetable matter is defective, disappointment will often follow the sowing of the most carefully selected seeds. By the agency, among other causes, of those above adverted to, *the soil gradually changes*, so that it is unfit, when first laid down, to bear those grasses which, ten or twenty years afterwards, will spontaneously and luxuriantly grow upon it. Nature is not regulated by one principle in the growth of corn and by another in growing grass; the apparent difference in her procedure arises from real differences in our practice.

CHAPTER XVI.

LIME: ITS USES IN AGRICULTURE.

The use of lime is of the greatest importance in practical agriculture. It has been employed in the forms of marl, shells, shell-sand, coral, chalk, limestone, limestone gravel, quicklime, &c., in almost every country, and from the most remote period.

Composition of Limestones and Chalks.—When diluted muriatic acid, or strong vinegar, is poured upon pieces of limestone, chalk, common soda, or common pearl-ash, effervescence takes place, and carbon dioxide gas is given off (p. 35). If a current of this gas be made to pass through lime-water (see fig. 21), the liquid becomes milky, and a white powder falls, which is pure *calcic carbonate*. It consists of—

	Per cent.
Carbon dioxide (CO_2), ...	44
Lime (CaO), ...	56
	100

Limestone, marble, and chalk consist, for the most part, of calcic carbonate. In soft chalk, the particles are held more loosely together; in the hard chalks and in limestones, the minute grains have been pressed or otherwise brought more closely together, so as to form a more solid and compact mass.

In regard to limestones and chalks, there are several circumstances which it is of importance for the practical man to know For example—

sidered less valuable for agricultural purposes. They can be applied less freely and abundantly to the land, and possess what practical men call a burning or scorching quality. They are, however, preferred to purer limes in some districts, as in the highlands of Galloway, for application to hill-pastures.

ANALYSES OF LIMESTONES FOR PENRITH FARMER'S CLUB, BY PROFESSOR ANDERSON, GLASGOW.

(4 out of 10 specimens).

Quarry.	Calcic carbonate.	Magnesic carbonate.	Iron oxide and alumina.	Insoluble matter.
Lowther village, .	84.50	0.88	0.82	13.80
Alston Moor, .	97.31	1.43	0.18	1.08
Ravenstonedale, .	95.20	1.67	0.56	2.57
Brampton, . .	94.80	2.36	0.81	2.03

No phosphate or sulphate of calcium could be found.

Composition of Corals, Shell-sands, and Marls.—1. *Corals*, as they are gathered fresh from the sea on the Irish (Bantry Bay) and other coasts, contain, besides calcic carbonate, a small percentage of calcic phosphate, and sometimes not less than 14 per cent of animal matter. This animal matter adds considerably to the fertilising value of coral-sand, when laid upon the land in a recent state, or when made into compost.

2. *Shell-sand* consists of the fragments of broken shells of various sizes, mixed with a variable proportion of sea-sand. It contains less animal matter than the recent corals, and its value is diminished by the admixture of sand, which varies from 20 to 70 per cent of the whole weight. On the shores of many of the Western Islands, shell-sand is found in large quantities, and is extensively and beneficially applied, especially to the hillside pastures and to peaty soils.

3. *Marls* consist of calcic carbonate — generally the fragments of shells—mixed with sand, clay, or peat, in various proportions. They contain from 5 to as much as 80 or 90 per cent of calcic carbonate, and are considered more or less rich and valuable for agricultural purposes as the proportion of lime increases. They are formed, for the most part, from accumulations of shells at the bottom of fresh-water lakes which have gradually been filled up by clay or sand, or by the growth of peat.

The Burning and Slaking of Lime.—1. *Burning.*—Limestones, when of a pure variety, consist almost entirely of calcic carbonate, which, as we have seen, contains 56 per cent of lime, or 11¼ cwt. to the ton.

When this limestone is put into a kiln, with as much coal as, when set on fire, will raise it to a sufficiently high temperature, the carbonic acid is driven off in the form of gas, leaving the pure lime behind.

In this state it is known as burnt lime, lime-shells, caustic lime, and quicklime, and possesses properties very different from those of the unburnt limestone. It has a hot, alkaline flavour, absorbs water with great rapidity, falls to powder, or slakes, and finally dissolves in 732 times its weight of cold water. This solution is known by the name of lime-water.

2. *Slaking.*—Its tendency to combine chemically with water is shown in the process of slaking. Almost every one is familiar with the fact that, when water is poured upon quicklime, it heats, emits steam, swells, cracks, and at last falls to a fine, usually white, powder, which is two or three times as bulky as the lime in its unslaked state. When thus fully slaked and cool, the fine powder consists of—

Lime, ...	76 per cent (nearly).
Water, ...	24 ,,
	100

Or 20 cwt. of pure burnt lime absorb and retain in the solid state 6⅓ cwt. of water, forming 26⅓ cwt. of slaked lime, called *hydrate* of calcium by chemists.

When quicklime is left exposed to the air, even in dry weather, it gradually absorbs moisture from the atmosphere, and falls to powder without the artificial addition of water. In this case, however, it does not become sensibly hot as it does when it is slaked rapidly by immersion, or by pouring water upon it. Some chemists state that this powder contains both hydrate and carbonate of calcium.

Effects of exposing Lime to the Air.—When lime from the kiln is slaked by means of water, it still retains its quick or caustic quality. But if, after it has fallen to powder, it be left uncovered in the open air, it gradually absorbs carbonic acid from the atmosphere, gives off its water, and becomes reconverted into dry calcic carbonate.

When lime is allowed to slake spontaneously in the air, it first absorbs water, and slakes, and falls to powder, and then absorbs carbonic acid and is changed into carbonate.

But as soon as a portion of the lime slakes, it begins to absorb carbonic acid, probably long before the whole is slaked. Thus the two processes go on together; so that, in lime left to slake spontaneously, as it often is on our fields and headlands, the powder into which it falls consists in part of caustic hydrate, and in part of mild carbonate of calcium. Its composition is nearly as follows :—

		Per cent.
Calcic carbonate,		57.4
Calcic hydrate,	{ lime, 32.4 ; water, 10.2 }	42.6
		100

When it reaches this stage or composition, the remainder of the hydrate absorbs carbonic acid much more slowly, so that, when spread upon or mixed with the soil, it takes a much longer time to convert it into carbonate. At last, however, after a longer or shorter period of time, the whole of the lime becomes saturated with carbonic acid, and is brought back to the same state of mild *un*-caustic carbonate in which it existed in the native chalk or limestone before it was put into the kiln.

Advantages of Burning Lime.—If the lime return to the same chemical state of carbonate in which it existed in the state of chalk or limestone,—what is the benefit of burning it?

The benefits are partly mechanical and partly chemical.

a. We have seen that, on slaking, the burnt lime falls to an exceedingly fine bulky powder. When it afterwards becomes converted into carbonate, it still retains this exceedingly minute state of division; and thus, whether as caustic hydrate or as a mild carbonate, can be spread over a large surface, and be intimately mixed with the soil. No available mechanical means could be economically employed to reduce our limestones, or even our softer chalks, to a powder of equal fineness.

b. By burning, the lime is brought into a caustic state, which it retains, as we have seen, for a longer

or shorter period, till it again absorbs carbonic acid from the air or from the soil. In this caustic state, its action upon the soil and upon organic matter is more energetic than in the state of mild lime; and thus it is fitted to produce effects which mere powdered limestone or chalk could not bring about at all, or to produce them more effectually, and in a shorter period of time.

c. Limestones often contain sulphur in combination with iron (iron pyrites). The coal or peat, with which it is burnt, also contains sulphur. During the burning, a portion of this sulphur (oxidised) unites with the lime to form gypsum, by this means adding to the proportion of this substance, which naturally exists in the limestone.

d. Earthy and silicious matters are sometimes present in considerable quantity in our limestone rocks. When burnt in the kiln, the silica of this earthy matter unites with lime to form *calcic silicate.* This silicate being diffused through the burnt and slaked lime, and afterwards spread, in a minute state of division, over the soil, is in a condition in which it may yield silica to the growing plant, supposing silica to be essential.

Thus the benefits of burning are, as we have seen, partly mechanical and partly chemical. They are mechanical, inasmuch as, by slaking, the burnt lime can be reduced to a much finer and more bulky powder than the limestone could be by any mechanical means; and they are chemical, inasmuch as, by burning, the lime is brought into a more active and caustic state, and is, at the same time, mixed with variable proportions of sulphate and of silicate of

lime—which may render it more useful to the growing crops.

Quantity of Lime applied per Acre.—The quantity of quicklime laid on at a single dressing, and the frequency with which it may be repeated, depend upon the kind of land, upon the depth of the soil, upon the quantity and kind of vegetable matter which the soil contains, and upon the species of culture to which it is subjected. If the land be wet, or badly drained, a larger application is necessary to produce the same effect, and it must be more frequently repeated. But when the soil is thin, a smaller addition will thoroughly impregnate the whole, than where the the plough usually descends to the depth of 8 or 10 inches. On old pasture-lands, where the tender grasses live in 2 or 3 inches of soil only, a feeble dressing, more frequently repeated, appears to be the more reasonable practice; though in reclaiming and in laying down land to grass, a heavy first liming is often indispensable.

In arable culture, larger and less frequent doses are admissible, both because the soil through which the roots penetrate must necessarily be deeper, and because the tendency to sink beyond the reach of the roots is generally counteracted by the frequent turning up of the earth by the plough. Where vegetable matter abounds, much lime may be usefully added; and on stiff clay lands, after draining, its good effects are very remarkable. On light land, chiefly because there is neither moisture nor vegetable matter present in sufficient quantity, very large applications of lime are not so usual, and it is generally preferable to add it to such land in the state of compost only.

The largest doses, however, which are applied in practice, alter in a very immaterial degree the chemical composition of the soil. The best soils generally contain a natural proportion of lime, not fixed in quantity, yet scarcely ever wholly wanting. But an ordinary liming, when well mixed up with a deep soil, will rarely amount to *one per cent* of its entire weight. It requires about 400 bushels (12 to 15 tons) of burnt lime per acre to add one per cent of lime to a soil of 12 inches in depth. If only mixed to a depth of 6 inches, this quantity would add about two per cent to the soil.

Though the form in which lime is applied, the dose laid on, and the interval between the doses, varies, yet in Great Britain, at least in those places where lime can be obtained at a reasonable rate, the quantity applied amounts, on an average, to from 7 to 10 bushels a-year.

Improvements produced by Lime.—The most remarkable visible alterations produced by lime are,—upon *pastures*, a greater fineness, sweetness, closeness, and nutritive character of the grasses—on *arable lands*, the improvement in the texture and mellowness of stiff clays, the more productive crops, their better quality and the earlier period at which they ripen, compared with those grown upon soils to which no lime has ever been added. It is said to destroy sorrel.

This influence of lime is well seen when limed is compared with unlimed land, or when soils which are naturally rich in lime are compared with such as contain but little. Barley grown on the former is of better malting quality. The turnips of well-limed

land are more feeding for both cattle and sheep. And the hill-pastures on limestone soils, like those of Derbyshire, continue longer green in autumn, and yield a greater yearly return of milk and cheese, than the soils which are produced from sandstone rocks.

Repeated Applications of Lime.—The superior condition produced in the soil by liming gradually diminishes year by year, in land artificially limed, till it returns again nearly to its original condition. On analysing the soil when it has reached this state, the lime which had been added is found to be in a great measure gone. In this condition the land must either be limed again, or must be left to produce sickly and unremunerating crops.

This removal of the lime arises from several causes.

1. *The lime naturally sinks,*—more slowly perhaps in arable than in pasture or meadow land, because the plough is continually bringing it to the surface again. But even in arable land, it gets at last beyond the reach of the plough, so that either a new dose must be added to the upper soil, or a deeper ploughing must bring it again to the surface.

2. *The crops carry away a portion of lime from the soil.*—Thus the following crops, including grain and straw, or tops and bulbs, carry off respectively—

			Of lime.
25	bushels	wheat, about . .	13 lb.
40	,,	barley, ...	17 ,,
50	,,	oats, ...	22 ,,
20	tons of	turnips, about . .	118 ,,
8	,,	potatoes, . . .	40 ,,
2	,,	red clover, . . .	77 ,,
2	,,	rye-grass, . . .	30 ,,

The above quantities are not constant, and much

of the lime is no doubt returned to the land in the straw, the tops, and the manure; yet still the land cannot fail to suffer a certain annual loss of lime from this cause.

3. *The rains wash out lime from the land.*—The rain-water that descends upon the land holds in solution carbonic acid which it has absorbed from the air. But water charged with carbonic acid is capable of dissolving carbonate of calcium; and thus year after year the rains, as they sink to the drains, or run over the surface, slowly remove a portion of the lime which the soil contains. Acid substances are also formed naturally by the decay of vegetable matter in the land, by which another portion of the lime is rendered easily soluble in water, and therefore readily removable by every shower that falls. It is a necessary consequence of this action of the rains, that lime must be added more frequently, or in larger doses, where much rain falls than where the climate is comparatively dry.

Circumstances which modify the Effects of Lime.—There are four circumstances of great practical importance in regard to the action of lime which cannot be too carefully borne in mind. These are:—

1. That lime has little or no marked effect upon soils in which organic—that is, animal or vegetable—matter is greatly deficient.

2. That its apparent effect is inconsiderable during the first year after its application, compared with that which it produces in the second and third years.

3. That its effect is most sensible when it is kept near the surface of the soil, and gradually becomes less as it sinks towards the subsoil. And,

4. That under the influence of lime the organic matter of the soil disappears more rapidly than it otherwise would do, and that, as this organic matter becomes less in quantity, fresh additions of lime produce a less sensible effect.

Chemical Effects of Lime upon the Soil.—The chemical effects of lime upon the soil in the caustic and mild states are chiefly the following:—

a. When laid upon the land in the *caustic* state, the first action of lime is to combine immediately with every portion of free acid matter it may contain, and thus to sweeten the soil. Some of the compounds it thus forms being soluble in water, enter into the roots and feed the plant, or are washed out by the springs and rains; while other compounds which are insoluble remain more permanently in the soil.

b. Another portion decomposes certain saline compounds of iron, manganese, and alumina, which naturally form themselves in the soil, and thus renders them unhurtful to vegetation. A similar action is exerted upon some of the compounds of potash, soda, and ammonia—if any such are present—by which these substances are set at liberty, and placed within the reach of the plant.

c. Its presence in the caustic state further disposes the organic matter of the soil to undergo *more rapid* decomposition—it being observed that, where lime is present in readiness to combine with the substances produced during the decay of organic matter, this decay, if other circumstances be favourable, will proceed with much greater rapidity. The reader will not fail to recollect that, during the decomposition

of organic substances in the soil, many compounds are formed which are of importance in promoting vegetation.

d. It is known that a portion at least of the nitrogen which naturally exists in the decaying vegetable matter of the soil is in a state in which it is very sparingly soluble, and therefore becomes directly available to plants with extreme slowness. But when heated with slaked lime in our laboratories, such compounds readily give off their nitrogen in the form of ammonia. It is not unlikely, therefore, that hot lime produces a similar change in the soil, though more slowly—hastening, as above stated, the general decomposition of the whole organic matter, but specially separating the nitrogen, and causing or enabling it to assume the form, first of ammonia, and afterwards of nitric acid, both of which compounds the roots of plants can readily absorb.

e. Further, quicklime has the advantage of being soluble to a considerable extent in cold water, forming lime-water. Thus the complete diffusion of lime through the soil is aided by the power of water to carry it in solution in every direction.

Chemical Effects of Mild Lime applied to the Soil.—When it has absorbed carbonic acid, and become reconverted into carbonate, the original caustic lime has no *chemical* virtue over chalk or crushed limestone, rich shell-sand, or marl. It has, however, the important *mechanical* advantage of being in the form of a far finer powder than any to which we can reduce the limestone by art—in consequence of which it can be more uniformly diffused through the soil, and placed within the reach of every root, and of

almost every particle of vegetable matter that is undergoing decay. We shall mention only three of the important purposes which, in this state of *carbon ate*, lime serves upon the land.

a. It directly affords food to the plant, which, as we have seen, languishes where lime is not attainable. It serves also to convey other food to the roots in a state in which it can be made available to vegetable growth.

b. It neutralises (removes the *sourness* of) all acid substances as they are formed in the soil, and thus keeps the land in a condition to nourish the tenderest plants. This is one of the important agencies of shell-sand, when laid on undrained grass or boggy lands; and this effect it produces, in common with wood-ashes and many similar substances.

c. During the decay of organic matter in the soil, it aids and promotes the slow natural production of nitric acid. With this acid it combines and forms *nitrate of calcium*—a substance very soluble in water—entering readily, therefore, into the roots of plants, and producing effects upon their growth which are very similar to those of the now well-known "*nitrate of soda.*" The success of frequent ploughings, harrowings, hoeings, and other modes of stirring the land, is partly owing to the facilities which these operations afford for the production of this and other natural nitrates.

Over-liming and its Remedy.—It is known that the frequent addition of lime, even to comparatively stiff soils long kept in arable culture, will at length so open them that the wheat crop becomes uncertain, and is especially liable to be thrown out in winter.

To lighter soils, again, and especially to such as are reclaimed from a state of heath, and contain much vegetable matter, the addition of a large dose of lime opens and loosens them, often to such a degree that they sound hollow, and sink under the foot. This effect is usually ascribed to an overdose of lime, and the land is commonly said to be *over-limed.* In this state it refuses to grow oats and clover, though turnips and barley thrive well upon it.

Analyses of over-limed soils have shown that it is not an excess of lime which produces the evil, but a too porous or loose condition of the soil, which admits of the following remedies:—

a. To eat off the turnips produced upon such soils with sheep;—or,

b. To consolidate the loose and open soil by the use of a heavy roller, a clod-crusher or peg-roller, or other similar mechanical means;—or,

c. To use the cultivator as much as possible instead of the plough, and thus to avoid the artificial loosening of the soil which is caused by frequent ploughing.

Still the questions were unsolved,—In what way does the lime produce, or aid the plough in producing, this opening of the soil?—and how are these effects to be prevented in future?

Let us hazard the conjectural explanation of this matter:—

1. The lime, in whatever state it is added to the land, assumes in a short time the state of carbonate.

2. In soils which are rich in decaying vegetables, much acid matter is gradually produced by the action of the air. The acids thus produced decompose the

carbonate of lime, and liberate its carbonic acid more or less copiously.

3. The effect of this liberation of the carbonic acid gas *may* be to heave up the land, to loosen it and lighten it under the foot. In heavy lands this may be less perceived, both because they are naturally denser and more difficult to heave up, and because they contain less vegetable matter, and consequently produce less of these acid substances in the soil. In light peaty or thin moorish soils, however, which are rich in decaying plants, the particles of soil are more readily lifted up and separated from one another.

Will this supposed action never cease? It is doubtful if it will, until the nature of the soil is altered, —by the gradual removal of the lime—by a diminution of the quantity, and a change in the nature of the decaying vegetable matter—or by a *permanent* solidifying of the land.

This last change may be effected either by a top-dressing of clay, sand, limestone - gravel, or other heavy matter, or by bringing up a heavier subsoil from below. Where the temporary solidification produced by eating off with sheep, and the use of a roller, is not approved of, the improvement of *over-limed* land is to be sought for in draining, subsoiling so as to admit the air into the under-soil, and, after a time, in bringing up and mixing with the surface a sufficient portion of this under-soil.

Exhausting Effects of Lime.—The exhausting effects of lime have been remarked from the earliest times. It causes larger crops to grow for a certain number of years, after which the produce diminishes, till at length it becomes less than before lime was applied

to it. Hence the origin of the proverb that "Lime enriches the fathers and impoverishes the sons."

Two interesting questions, therefore, suggest themselves in connection with this circumstance. How is this exhaustion produced? Is it a necessary consequence of the addition of lime, or can it be prevented?

It has already been stated that lime promotes those chemical changes of the organic part of the soil by which it is rendered more serviceable to the growth of plants. But in consequence of this action, the proportion of organic matter in the soil gradually diminishes under the prolonged action of lime, and thus the soil becomes less rich in those substances of organic origin on which its fertility in some degree depends.

Again, lime acts also on the mineral matter of the soil, and prepares it for more abundantly feeding the plant.

Now, as the crops we reap carry off not only organic but mineral matter also from the soil, anything which prepares that mineral matter more abundantly for the use of the plant must cause also a more rapid diminution of those mineral substances on which, as well as upon its organic matter, the fruitfulness of the soil is dependent.

By this mode of action, therefore, arises the exhaustion which universal experience has ascribed to the use of lime.

But without reference to the chemical processes by which it is brought about, a common-sense view of the question sufficiently explains how the exhaustion arises.

It is conceded that the crops we grow rob the soil both of organic and inorganic matter. A double crop will take twice as much, a triple crop three times as much, and so on. And the more we take out in one year, the more rapidly will the land be exhausted. Now, if lime, by its mode of action, enables us in the same time to extract three or four times as much matter from the soil in the form of increased crops, it must so much the more rapidly exhaust the soil, in the same way as we should drain a well sooner by taking out fifty than by removing only five gallons a-day.

But we can restore to the soil what crops carry off. By farmyard-manure, and by saline applications, we can return everything which lime enables us thus to extract, and we can thus preserve its fertility unimpaired. Manure, therefore, in proportion to the crops taken off, and lime will cease to be exhausting. There is much wisdom in the rhyme—

> "Lime and lime *without manure*,
> Will make both land and farmer poor."

CHAPTER XVII.

IMPROVEMENT OF SOILS BY PARING AND BURNING THEIR SURFACE.

A mode of improvement often resorted to on poor lands is the paring and burning of the surface. The

effect of this treatment is easily understood. The matted sods consist of a mixture of much vegetable, with a comparatively small quantity of earthy, matter. When these are burnt, the ash only of the plants is left, intimately mixed with the calcined earth. To strew this mixture over the soil is much the same as to dress it with peat or wood ashes, the beneficial effects of which are almost universally recognised. And the favourable influence of the ash itself is chiefly due to the ready supply of inorganic food it yields to the seed, and to the effect which the potash and soda, &c., which it contains, exercise either in preparing organic food in the soil, or in assisting its assimilation in the interior of the plant.

Another part of this process is, that the roots of the weeds and poorer grasses are materially injured by the paring, and that the subsequent dressing of ashes is unfavourable to their further growth.

It is besides alleged, that poor old grass-land, when ploughed up, is sometimes so full of insects that the success of any corn or green crop put into it becomes very doubtful. When pared, these insects collect in the sod, and are destroyed by the subsequent burning.

Chemical Changes produced by Burning Clays.—When a soil is burnt, the organic portion of it is altogether, or nearly altogether, destroyed; the combustible (volatile) portion escapes into the atmosphere in the form of water, carbonic acid, &c.; whilst its earthy and saline constituents remain in the soil in the form of a powder more or less fine. The soil loses nearly all its nitrogen in this way, but then, such soils as are suitable for burning, rarely contain much nitrogen in a condition in which it is

available for crops. The saline and earthy substances derived from the combustion of the organic matter are, of course, identical with the mineral constituents of plants; being in a pulverulent condition, they are the more readily absorbed by the growing vegetables.

In all soils capable of nourishing even the most worthless weed, there must be potash. This substance exists in soils for the most part in combination with silica, and in such a form as to be insoluble in the solvents present in soils. That is, though there may be abundance of potash in the soil, yet it is mostly insoluble, and not immediately available for the nourishment of plants. By the action of frosts and by other agents the rocky portions of the soil in which the potash is bound up become broken up and reduced to powder; during this operation potash is gradually set free, so to speak, and placed at the disposal of the plant. Burning the soil expedites its disintegration and liberates not only its potash, but some of its other constituents. In an experiment made by Dr Voelcker, he found that unburnt clay contained 0.269 per cent of soluble potash, whilst the same clay after burning contained 0.941 per cent of potash soluble in acidulated water. One most important change produced in soils by burning is therefore a great increase in the amount of soluble potash.

It would appear that it is lime which displaces potash from its combination with silica, when the potassic silicate of soils is highly heated. Burning, therefore, diminishes the amount of calcic carbonate in soils. In the first place carbonic acid is expelled from the carbonate ($CaCO_3 = CaO + CO_2$), and caustic lime thereby formed decomposes the silicate of

potassium, producing free potash and calcic silicate It may happen, too, that part of the calcic carbonate directly decomposes the silicate, forming, by double decomposition, calcic silicate and potassic carbonate, as suggested by Voelcker. Soda is not in general so abundant in soils as potash; but, when it is present, its soluble portion is increased by the operation of burning. The amounts of oxide of iron and alumina in clays soluble in acid solutions are greatly increased by burning; on the other hand, the proportion of soluble phosphoric acid is considerably diminished. This is certainly an unfavourable point in the operation of burning.

The quantity of ammonia contained in the soil is largely diminished by burning, but the burnt soil acquires a greater aptitude for absorbing ammonia from the atmosphere. As the mechanical changes produced in clays by burning are not sufficient to account * for the augmented productiveness, it is evident that the improvement must be due to an increase in the amount of soluble matter. The great increase in the proportion of soluble potash appears, therefore, to more than compensate for the diminished amount of soluble phosphoric acid. There are few artificial manures used in which potash is an important ingredient, whilst with two or three exceptions phosphoric acid is their most abundant. The results of experiments with burnt clay would seem to indicate that potash is as valuable a manure as phosphoric acid; for by increasing the amount of the former and diminishing that of the latter in a soil, the fertility of the soil is exalted.

* Johnston's Experimental Agriculture, page 261.

Mechanical Effects of Burning Soils.—Clays which require to be burnt are usually very stiff and tenacious. They are cultivated with difficulty and at considerable cost. When burnt these soils become loose, friable, and easily worked. Stiff soils are cold and wet. Air circulates slowly throughout their interior, and water stagnates in them. These defects are obviously remedied by burning. Stiff soils which for purely mechanical reasons are not adapted for the growth of green crops may be rendered so by burning. On the other hand, soils which consist nearly altogether of insoluble peaty matter, may be converted into good soil by the combustion of their organic ingredients.

Over-burning Soils.—When the soil is burnt at too high or too prolonged a temperature, it is not much improved by the operation. Voelcker found that the amount of soluble potash in clay was increased from 0.269 to 0.941 per cent by moderate burning, and only to 0.544 by a high and prolonged heat. Over-burnt clay, instead of being pulverulent, is in the form of hard lumps like pieces of brickbat. One ton of coal should suffice to burn 50 cubic yards of clay; but wood or peat (turf) are probably better kinds of fuel to use, as they do not produce by their combustion so high a temperature as coal does.

Soils fit for Burning.—Stiff, intractable clays are those which alone (with the exception of peats) are suitable for burning. If they do not contain a sensible amount of lime, the chemical changes necessary to an increase of their fertilising power cannot take place. The deficiency of lime must therefore be made up. Lime is often added to burnt clay, but it is better to

mix it with the soil before it is burnt. When a soil is properly burnt, it is not necessary to repeat the operation.

Fertility of Burnt Clays.—There is abundant evidence as to the fertility of burnt clay. Mr C. Randell, in the 'Journal of the Royal Agricultural Society of England,' vol. xxiv. (1863), states, that twenty-two years' experience of the effects of burning land have convinced him of the great benefits derivable from that operation. He refers to several fields which had been burnt twenty years previously, and in which the improvement thereby effected had continued undiminished in the slightest degree. Mr Pusey found a dressing of burnt Oxford clay to increase his wheat crop from 37¾ to 45½ bushels per imperial acre. And Mr Danger, who farms on the New Red Sandstone, near Bridgewater, says, that a soil which he found "quite sterile, has, by the application of burnt clay, become totally changed." *

It is equally true, however, that burnt clay has often failed to do any good—that the practice of burning clay, which is common in some districts, is for this reason never adopted in others—and that clay from the same locality may or may not do good according to the method of burning. All this is easily explained when the true cause of the chemical action of burnt clay is understood.

50 to 100 tons of burnt clay to an acre is not an unusual application. Now, at 36 lb. to the ton, the largest dose would yield to water not less than 3600† lb. of soluble mineral matter; while the whole quan-

* Journal of Royal Agricultural Society, vi. 477, and xii. 509.

† Experimental Agriculture, 261.

tity of such matter carried off in a four-years' rotation, from our best farms, is only 1300 lb. It is not surprising, therefore, knowing, as we do, how applications of saline matter increase the crops, that so great and ready a supply of such matter in the burnt clay should produce a marked effect upon the fertility of the land upon which it is spread.

But, further, all clays have not the same composition. Some contain more lime, others more magnesia, others more potash or soda, and others more phosphoric acid ; while some, again, contain so little of any of these substances as to produce no sensible effect when burnt and laid upon the land. Thus the chemical composition of a clay determines whether or not it can be burnt and applied with advantage.

Advantage is taken of the porous quality of burnt clay by some English farmers—as, for example, by Mr Randell of Chadbury, near Evesham—to absorb and preserve the droppings of sheep. Under house-fed sheep, kept upon boards or otherwise, a layer of burnt clay is spread, upon which the droppings fall : from time to time fresh layers are added to the surface, till it becomes necessary to remove the whole. In this way, the odour of the dung never becomes excessive, and the clay is rendered so rich that 10 tons of it are found equal (it is stated), in the raising of turnips, to 4 cwt. of guano.

CHAPTER XVIII.

THE IMPROVEMENT OF THE LAND BY IRRIGATION.

About 100,000 acres of land are irrigated in the United Kingdom; but this practice is more prevalent in many Continental States.

The irrigation of the land is, in general, only a more refined method of manuring it. The nature of the process itself, however, is different in different countries, as are also the kind and degree of effect it produces, and the theory by which these effects are to be explained.

In dry and arid climates, where rain rarely falls, the soil may contain all the elements of fertility, and require only water to call them into operation. In such cases—as in the irrigations practised so extensively in Eastern countries, and without which whole provinces in India and Southern America would lie waste—it is unnecessary to suppose any other virtue in irrigation than the mere supply of water it affords to the parched and cracking soil.

But in climates such as our own, there are several other beneficial purposes in reference to the soil, which irrigation may, and some of which at least it always does, serve—thus,

The occasional flow of *pure* water over the surface, as in our irrigated meadows, and its descent into the drains, where the drainage is perfect, washes out acid and other noxious substances naturally generated in the soil, and thus purifies and sweetens it. The bene-

ficial effect of such washing will be readily under stood in the case of peat-lands laid down in water-meadow, since, as every one knows, peaty soils abound in matters unfavourable to general vegetation. These substances are usually in part drawn off by drainage, and in part destroyed by lime and by exposure to the air, before boggy lands can be brought into profitable cultivation.

Nature of Drainage Waters.—But it seldom happens that perfectly *pure* water is employed for the purposes of irrigation. The waters of rivers, as they are diverted from their course for this purpose, are more or less loaded with mud and other fine particles of matter, which are either gradually filtered from them as they pass over and through the soil, or, in the case of floods, subside naturally when the waters come to rest. Or in less frequent cases, the drainings of towns and the water from common sewers, or from the little streams enriched by them, are turned with benefit upon the favoured fields. These are evidently cases of gradual and uniform manuring.

Even where the water employed is clear and apparently undisturbed by mud, it almost always contains ammonia, nitric acid, and other organic and saline substances grateful to the plant in its search for food, and which plants always contrive to extract, more or less copiously, as the water passes over their leaves or along their roots. The purest spring-waters and mountain-streams are never entirely free from impregnations of mineral and vegetable or animal matter. Every fresh access of water, therefore, affords the grass in reality another liquid manuring.

The kind of saline substances which spring-water or

that of brooks contains depends upon the nature of the rocks or soils from which it issues or over which it runs. In countries where granite or mica-slate abounds, potash and soda, and even magnesia, may be expected in notable quantities; while in limestone districts the waters are generally charged with lime. When spread over the fields, these latter waters supply lime to the growing plants, and so affect the general fertility of the soil as to render almost unnecessary the direct application of lime to the land. The value of the mountain-streams for the purpose of irrigation in limestone districts is so well known, that some have been inclined to undervalue all the constituents of natural waters, and to ascribe little worth as irrigators to the clear waters of brooks and springs which are not rich in lime. This opinion, however, is not in accordance with the results of the analyses of waters which have been profitably employed for irrigation.

Flowing water also drinks in from the air, as it passes along, a portion of the oxygen and carbonic acid of which the atmosphere in part consists. These gaseous substances it brings in contact with the leaves at every moment, or it carries them down to the roots in a form in which they can be readily absorbed by the parts of the plant. It is not unlikely that, in consequence of this mode of action, even *absolutely* pure water would act beneficially if employed in irrigating the soil.

Further, the constant presence of water keeps all the parts of the plant in a moist state, allows the pores of the leaves and stems to remain open, retards the formation of hard woody fibre, and thus enables

the growing vegetable, in the same space of time, to extract a larger supply of food, especially from the air. In other words, it promotes and enlarges its growth.

In the refreshment continually afforded to the plant by a plentiful supply of water—in the removal of noxious substances from the soil—in the frequent additions of enriching food, saline, organic, or gaseous, to the land—in the soft and porous state in which it retains the parts of the plant, the efficiency of irrigation seems almost entirely to consist.

It is known that waters which have passed over the surface of a field become sensibly less fertilising. This is easily explained by the reasonable supposition that the plants among which they have flowed have deprived them of a portion of their enriching matter.

Waters vary in their Fertilising Properties.—But in the same neighbourhood, it has been often observed that waters from natural springs which are perfectly alike in appearance, yet differ remarkably in their value for irrigation. Such is the case among the mountains of the Vosges, where irrigation is much attended to. The same quantity of water, from two neighbouring springs, for example, employed on two adjoining meadows of similar quality, gave of hay per acre—

	1st cutting.	2d cutting.	Total.
Good spring, .	58 cwt.	24 cwt.	82 cwt.
Bad spring, . .	14 ,,	7½ ,,	21½ ,,

Or the good spring produced nearly four times as much hay as the bad one.

A chemical examination of the waters of the two springs satisfied the experimenters (Chevandier and Salvetat) that this difference was not due, either

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certain substances from their solutions, and of retair ing those substances when subjected to the influenc of flowing water.

Thompson's and Way's Experiments.—The earliest experiments in reference to the absorptive power of soils were made in 1845 by Messrs Thompson and Spence. They proved that soils possessed the property of absorbing and retaining ammonia from a solution of its carbonate or sulphate, when filtered through them. In 1850, 1852, and 1855, Mr Way published papers in the Journal of the Royal Agricultural Society of England, on the power of soils to absorb and retain manure. The nature of Way's experiments, which are in the highest degree interesting and important, may be briefly described as follows:—A number of solutions of various substances, such as common salt, sal-ammoniac, potassic nitrate, &c., were filtered through a layer of clay, 10 or more inches in depth. Each solution, after filtration, was carefully analysed, and with few exceptions was found to have lost all, or a portion, of the solid substance which it had contained previous to being filtered. It was found that carbonate and phosphate of ammonium, and "super-phosphate of lime," were altogether removed from solution by the soil; whilst, on the other hand, the nitrates, sulphates, and chlorides of ammonium, potassium, sodium, &c., left only heir bases in the soil, their solutions after filtration ontaining only sulphuric, nitric, or hydrochloric cid, according to the nature of the salt. Way found at, as a rule, it was the base, and not the acid of salt which soils had the power of absorbing from lution.

In Way's experiments the various solutions were not only filtered through layers of soil, but were also shaken up with weighed portions of the latter. The latter process is generally adopted by recent investigators into the absorptive power of soils.

All Soils have not equal Power in Absorbing Manure.—Every kind of soil possesses the power of absorbing bases from their solution, but in some, this faculty is developed in a higher degree than in others. Porous arable soils act more powerfully than very stiff, adhesive clays. Peaty soils are tolerably absorbent. According to Voelcker (Journal of Royal Agricultural Society, vol. xxi. 1860) there is not very much difference between the absorptive powers of a sandy soil as compared with a calcareous or clay one. The general results of experiments show, however, that sands are not equal to loams as absorbents of manures.

A soil has not an unlimited capacity for absorbing manurial matters. If a solution of, say, ammonic phosphate be passed for some time through a weighed quantity of soil, it will, after a certain time, pass through unchanged. If, however, we filter one pint of solution of ammonic phosphate through a portion of soil, the ammonia and phosphoric acid retained by the latter will not even, except in very small part, be removed by filtering through the soil a pint of pure water. In other words, the soil has a greater power of removing ammonia, &c., from solution than water has of removing ammonia, &c., from the soil.

Certain Substances Absorbed in larger Quantities than others.—Some bases are taken up by the

soil in larger quantities than others. According to Kullenberg, the order in which they stand in this respect is as follows:—ammonium, potassium, magnesium, calcium, and sodium. The well-known manure, "nitrate of soda," is not retained to any great extent by soils. It seems well established that phosphates and carbonates of bases are the salts absorbed in greatest quantities; but there are not sufficient experimental data with reference to the influence of nitric and sulphuric acids and chlorine in promoting or retarding the absorption of bases.

Theory of Absorptive Power of Soils.—At first Way believed that the fixation of bases in the soil was due to the action of lime; but subsequently he advanced the following theory:—In soils there are double silicates (silicate of aluminium combined with silicate of calcium, &c.) If potash be brought into contact with this double silicate, it replaces the lime. Sulphate of potassium, and double silicate of aluminium and calcium, produce sulphate of calcium and double silicate of aluminium and potassium. Silicate of aluminium appears to combine with most avidity with ammonium, and least so with sodium. Many chemists, whilst admitting that aluminic silicate really does absorb ammonia, contend that the hydrated ferric oxide ($Fe_2O_33H_2O$) usually present, and to a large extent, in the soil, also takes up ammonia, &c. It is further advanced that hydrated alumina ($Al_2O_33H_2O$) exists in soils, and that it acts as an absorbent; but it is very doubtful whether or not uncombined alumina exists in ordinary soils. Warrington, Peters, and others, have with great show of reason claimed for ferric oxide (red oxide of iron) great absorptive

powers. That it acts upon the manure termed "superphosphate" there is but little doubt. In the first instance, the soluble phosphate, when placed in the soil, may be rendered insoluble by the action of lime, or of calcic or magnesic carbonate (* H_4Ca2PO_4 + † $2CaCO_3$ = ‡ Ca_32PO_4 + § $2CO_2$ + ‖ $2H_2O$), but subsequently the oxide of iron separates the lime, and, uniting with the phosphoric acid, forms a phosphate of iron. Bases, too, as well as acids, unite with the ferric oxide of soils. The theory of some chemists that the absorptive power of soils is purely a physical, and not a chemical, property, appears untenable; but no doubt the carbonaceous matters in peaty soils do absorb manure *apparently* much in the same way as charcoal takes up colouring matters from solutions filtered through it.

Do Plants absorb their Food from Solution?—The results of the experiments which have been here made relative to the absorption of acids and bases by soils, show that there is not that active circulation of fertilising substances throughout soils that was at one time believed to exist. The water which percolates through the soil carries but little useful matter along with it. Having these facts in view, Baron Von Liebig has suggested that plants do not take up their food in solution, seeing that it is so sparingly soluble in the liquid present in the soil. It seems, however, improbable that solid matters could pass into the organisms of plants; and we can hardly

* Tetrahydric calcic diphosphate (soluble phosphate).

† Calcic carbonate.

‡ Tricalcic diphosphate (insoluble phosphate).

§ Carbonic dioxide. ‖ Water.

accept Liebig's theory, at least in its entirety, until our knowledge of the physical condition in which the food of plants exists in the soil is considerably enlarged.

Analyses of Drainage Waters.—The composition of drainage waters has been investigated by several chemists. The following analyses have been made by Zöller :—

Composition of Drainage Water according to Zöller.

A Million Parts of Water contain	1.	2.	3.	4.	5.
Solid matters, . .	472.32	254.64	292.64	305.20	291.50
Ash therein, . .	317.62	176.74	196.78	214.50	212.16
Potash, . . .	6.50	2.37	2.03	5.46	3.82
Soda, . . .	7.11	5.60	7.43	23.74	6.02
Lime, . . .	145.86	57.60	70.80	68.41	92.34
Magnesia, . .	20.52	8.80	0.32	2.93	5.12
Ferric oxide, . .	1.32	6.35	8.26	5.76	4.30
Chlorine, . . .	57.49	9.52	20.87	39.46	35.27
Phosphoric anhydride,	2.23	...	...	...	...
Sulphuric anhydride,	17.47	27.13	27.82	29.30	33.49
Silica, . . .	10.46	11.35	17.46	9.50	9.36

1. From manured lime soil with vegetation; 2. Rough clay soil with vegetation; 3. Rough clay soil without vegetation; 4. Manured clay soil without vegetation; 5. Manured clay soil with vegetation.

Way's Experiments on Drainage.—Mr Way has published, in the 17th volume of the Journal of the Royal Agricultural Society of England, the following analyses of drainage water :—

COMPOSITION OF DRAINAGE WATER.

	Grains of Mineral Matter per gallon.						
	1.	2.	3.	4.	5.	6.	7.
Potash, . .	trace	trace	0.02	0.05	trace	0.22	trace
Soda, . .	1.00	2.17	2.26	0.87	1.42	1.40	3.20
Lime, . .	4.85	7.19	6.05	2.26	2.52	5.82	13.00
Magnesia, .	0.48	2.32	2.48	0.41	0.21	0.93	2.50
Oxide of Iron and Alumina, .	0.40	0.05	0.10	none	1.30	0.35	0.50
Silica, . .	0.95	0.45	0.55	1.20	1.80	0.65	0.85
Chlorine, .	0.70	1.10	1.27	0.81	1.26	1.21	2.62
Sulphuric Acid,	1.65	5.15	4.40	1.71	1.29	3.12	9.51
Phosphoric Acid,	trace	0.12	trace	trace	0.08	0.06	0.12

Nos. 1 and 2 drainages were collected from fields which had been well manured, but which a few years previously had been in very bad condition. No. 3 was collected from land which shortly before had formed part of a common. It had been manured only for a couple of years. No. 4 drainage flowed from a dirty gravel lying upon *gault.* For some years past it had been manured and limed. No. 5 drainage was obtained from land somewhat resembling that last described. No. 6 was derived from a heavily manured loam, 3 to 8 feet deep, and resting upon gravel. No. 7 was procured from a field which had been drained about 9 years previously, and which originally had formed part of a larch plantation.

The small quantities of potash and phosphoric acid, and the large proportions of lime and sulphuric acid, present in these drainage waters are remarkable features in their composition. Much of the sulphuric acid was probably obtained from superphosphate of lime, which it appears had been applied to all the soils. From this source also a portion of the lime was no doubt derived, and the rest from the soil or from lime which had been added to it.

Nitrogen in Drainage Waters. — Mr Way found the soluble organic matter to vary from 3.8 to 12 grains per gallon, the ammonia from 0.006 to 0.018 grain, and the nitric acid from 3.91 grains to 14.74 grains per gallon. The amount of nitrogen which passes out of the soil in the form of ammonia is insignificant, but perfectly oxidized nitrogen (nitric acid) goes off in large quantities in drainage. Frankland and Voelcker have analysed many specimens of drainage water from parts of Mr Lawes' experimental farm. Some of these results are given in the following table:—

COMPOSITION OF DRAINGE WATER FROM PLOTS DIFFERENTLY MANURED, BROADBALK FIELD, ROTHAMSTEAD.

The samples were collected at different periods of the year in 1866, 1867, 1868, 1872, and 1873.

Plots.	—	Nitrogen as Nitrates and Nitrites, per 100,000 parts of Drainage Water.					
		Dr Voelcker's Results.		Dr Frankland's Results.		Mean.	
		Experiments.		Experiments.		Experiments.	
2	14 tons farmyard manure, every year .	2	1.606	4	0.922	6	1.264
3-4	Without manure, every year . . .	5	0.390	6	0.316	11	0.353
5	Mineral manure alone	5	0.506	6	0.349	11	0.428
6	,, ,, and ammonia-salts (41 lb. nitrogen) . .	5	0.853	6	0.793	11	0.823
7	Mineral manure and ammonia-salts (82 lb. nitrogen) . .	5	1.400	6	1.477	11	1.439
8	Mineral manure and ammonia-salts (123 lb. nitrogen) . .	5	1.679	6	1.951	11	1.815
9	Mineral manure and nitrate soda (82 lb. nitrogen) . .	5	1.835	5	1.039	10	1.437

Wheat had been grown every year in this field since 1844.

According to the experimental results * of Mr Greaves, 28 per cent of the rain which fell on a certain soil penetrated to the depth of 36 inches. Messrs Lawes and Gilbert found that 36.8 per cent of the rain percolated to a depth of 20 inches. More than one-third of the rain which falls sinks deeply into the ground, and nearly two-thirds are evaporated.

Rainfall.—The amount of water which falls annually in the form of rain is enormous. There are few parts of the United Kingdom in which the rainfall is less than 25 inches per annum. At that rate an acre would receive annually 567,168 gallons, of which about 200,000 gallons sink deeply into the soil.

CHAPTER XX.

THE EXHAUSTION OF SOILS.

Stock of Plant-Food in Soils. — The quantity of mineral matter which even the most exhaustive crop removes from the soil is extremely small when compared with the amount which the crop leaves untouched. If, however, crop after crop be taken from the soil, and if no manure be given in return for the matters abstracted therefrom, can such a system be

* Proceedings of the Institution of Civil Engineers for 1875-76, part iii.

carried on for an indefinite period? Baron Liebig says emphatically that it cannot, and that such a system must inevitably, and at no very distant date, result in the exhaustion of the land. Indeed in many of his valuable works the great German chemist has drawn very gloomy pictures of the future condition of agriculture in most civilised countries. Large quantities of food substances are consumed in towns, and the effete matters which result therefrom, instead of being returned to the soil from which they were procured, are in the form of sewage discharged into the ocean, and lost to agriculture.

Lois Weedon Experiments.—The Rev. Mr Smith of Lois Weedon, on the other hand, insists that the quantity of plant-food in the soil is so enormous as to be practically inexhaustible. To prove this assertion, he grew in the same field, for nearly twenty years in succession, and without the use of any manure, excellent crops of wheat. So far back as 1773, Jethro Tull, the inventor of the English horse-drill sowing-machine and other valuable innovations, insisted upon the importance of the thorough cultivation of the soil, asserting that tillage was a substitute for manure.

There is no doubt but that in even an indifferent soil a great number of successive wheat crops can be grown without manure, and even with but a very moderate amount of culture. It must, however, be borne in mind that the amount of potash and phosphoric acid, the only mineral substances of real value removed from the soil by a wheat crop, does not exceed 50 pounds, or about one-fifth of the quantity which a turnip crop removes, if wholly consumed off

the fields which produced it. If mangels or turnips were grown year after year in the same field, without being manured, their roots would soon degenerate, and become small and worthless.

Rothamstead Experiments on Soil-Exhaustion.—The most extensive and accurately conducted experiments in relation to soil-exhaustion are those which have been carried on since 1843 up to the present by Messrs Lawes & Gilbert at Rothamstead, Harpenden, Hertfordshire. During twenty-eight years barley was continuously growing in the same field, without the application of either the natural or artificial manures. The yield of dressed corn per acre on one plot amounted annually, on the average of twenty-eight years, to 17⅞ bushels. In a second plot the annual average yield was 19½ bushels. During the first ten years the average annual produce in one plot amounted to 22⅜ bushels, and in the other to 25 bushels; whilst during the second decennial period, the average yearly crop in the first plot fell to 17½ bushels, and in the other plot to 18⅞ bushels per acre. The total amount of corn per acre in No. 1 plot was, on the average, 1281 lb. weight for the first ten years, and 985 lb. for the second decennial period. No. 2 plot yielded 1414 lb. for the first ten years, and 1070 lb. during the following ten years. The yields of straw and chaff were as follows:—1st plot, 13⅜ cwt. for the first period of ten years, and 10¼ cwt. during the second period. No. 2 plot gave 14 cwt. during the first, and 10¾ cwt. during the second ten years. The amount of produce (corn, straw, and chaff) was, therefore, 23.4 per cent less in the second ten years than in the first, in the case of plot No. 1, and 23.9

per cent less, in the case of plot No. 2. These results refer to the period 1852-1871, since which time a further annual decrease in the yield of corn and straw has been noticed. In 1879 the dressed corn (average of both plots) amounted to 7⅛ bushels, and the straw obtained weighed only 5⅞ cwt. During 28 years the average yield of dressed corn was 17⅞ bushels, and of straw, 10⅜ cwt. The produce of barley in 1880 was a very large one, from all the experimental plots. Wheat grown every year from 1852 to 1879 gave annually 15⅜ bushels of dressed corn and 14¼ cwt. of straw during the first fourteen years, and 11 bushels of dressed corn and 9⅝ cwt. of straw yearly during the following twelve years. In 1879 the yield of dressed corn was 4¾ bushels, and of straw 6⅞ cwt. The oat crop appears to diminish very rapidly in its produce when unmanured. In 1869, Messrs Lawes and Gilbert commenced an experiment with this crop, and obtained without manure 36⅝ bushels of dressed corn and 19¼ cwt. of straw. During the following years the produce diminished considerably, though in the last season of the experiment (1878), the yields of grass and straw were 22¼ bushels and 8⅜ cwt. respectively.

During twenty years, the wheat removed about 4700 lb. of mineral matter from the soil, of which about 253 lb. consisted of phosphoric acid and 360 lb. of potash. The soil at Rothamstead is a heavy loam, of medium quality. In a lighter soil it is probable that the available plant-food would have become earlier exhausted.

The results of the Rothamstead experiments show that it is possible to grow cereal (but not green) crops

year after year without the use of manure, but after a short time with a constantly decreasing produce. It might probably be found that a greater degree of cultivation, a more minute pulverisation of the soil, would in the case of the Rothamstead plots retard the decrease of the produce; but no amount of tillage could indefinitely postpone the exhaustion of the soil. No doubt it would require a very long time to produce this exhaustion. It has been estimated that in many soils the amounts of phosphoric acid and potash are sufficient for the requirements of hundreds of crops; but even if a particular soil contained 20 or 30 times as much phosphoric acid as a crop required, such a soil certainly would be found in practice almost infertile. It would be unproductive, because the plants grown in it would find it difficult to gather up their food from a comparatively scanty supply. Although the roots of plants ramify in a wonderful manner, they cannot be expected to come into contact with every particle of the soil. The great fact established by Messrs Lawes and Gilbert is, that whilst it is possible by a severe, and in practice unusual, course of cropping to reduce soils to comparative infertility, yet that the system of agriculture followed in these countries is not leading to that utter ruin predicted so eloquently by the great German philosopher, Liebig.

Exports and Imports of Fertilising Matters.—The quantities of nitrogen, phosphoric acid, and potash annually sent out of a farm in the produce thereof, depend to some extent upon the system of agriculture adopted. Let us, however, suppose with Dr Paul the case of a field under the following four-course rotation:—1st year, turnips (10 tons); 2d

year, barley (35 bushels); 3d year, clover-hay (5000 lb.), or beans (1500); 4th, wheat (30 bushels). The turnips and hay being consumed by cattle, and the straw of the barley and wheat being retained on the farm, the exports would consist of the grain, and the meat produced from the turnips and clover-hay. These would contain about 36 lb. of nitrogen, 30 lb. of phosphoric acid, and 19 lb. of potash. At this rate each acre would annually lose 9 lb. of nitrogen, 7½ lb. of phosphoric acid, and 4⅘ lb. of potash. Although these quantities are not large, yet in process of time they might have a serious effect upon the fertility of the land if not compensated for in some way. A portion of the nitrogen, &c., comes back to the land in the form of town manure; but the quantity obtained from this source is not large. The fish consumed in country districts also furnish a trifling quantity of nitrogen and ash constituents to the soil. About 7 lb. of combined nitrogen from rain, snow, and dew are obtained by each acre every year; and probably a large amount is absorbed directly from the atmosphere.* The losses which the soil sustains by drainage waters carrying off its nitrogen are, however, about compensated by the gain of nitrogen from the air. The substantial equivalent for the loss which the soil sustains by exporting a portion of its produce is the fertilising matter which it gains from imported foods

* According to Berthelot (Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences, October 9, 1876), atmospheric nitrogen is converted into compounds assimilable by plants, not merely by obvious electrical disturbances in the atmosphere (as already known), but by a hitherto unknown electric action, exercised unceasingly under the most serene sky.

and manures. Immense quantities of food are imported into these countries, and although when they are consumed the effete matters into which they are converted are chiefly discharged into sewers and rivers, still a portion is deposited in British soils. An enormous amount of oil-cakes and other feeding-stuffs is consumed on the farms of these countries, and as only a small portion of their weight becomes permanently reorganised into animal substances, their nitrogen, phosphoric acid, and potash, for the most part, go into the soil. The losses by exports are also in great part compensated by the imports of guano nitrate of soda, phosphates, and potash salts from foreign countries. The following table shows the extent of the gains from all these sources :—

IMPORTS INTO UNITED KINGDOM IN 1879.

ARTICLES.	CWT.	Containing per cent of— Nitrogen.	Phosphoric Anhydride.	Potash.	Total Quantities imported in Cwt. Nitrogen.	Phosphoric Anhydride.	Potash.
Meat,*	8,087,894	2.0	1.2	0.2	161,758	97,055	16,176
Cheese, ...	1,789,721	4.0	0.3	0.5	71,589	5,369	8,949
Eggs,†	855,701	2.15	0.3	0.1	18,398	2,567	856
Fish, ...	1,160,140	2.75	0.4	0.1	31,904	4,640	1,160
Grain and flour, . .	123,326,083	1.75	0.8	0.5	2,158,206	986,609	616,630
Rice, ...	6,857,300	0.98	0.17	0.6	67,202	11,657	41,144
Potatoes, ...	9,357,179	0.25	0.18	0.5	23,393	16,843	46,786
Flax and rape seeds, .	9,393,098	3.4	1.1	0.9	319,365	103,324	84,538
Grass and clover seeds,	1,477,693	3.0	1.0	1.25	44,331	14,777	18,471
Oil-cakes, ...	4,343,680	4.5	1.5	1.2	195,466	65,155	52,124
Guano, ...	1,540,300	8.5	15.0	2.0	130,925	231,045	30,806
Artificial manures,‡ .	10,000,000	1.0	15.0	0.2	100,000	1,500,000	20,000
					3,322,537	3,039,041	937,640

* Including 247,768 oxen, bulls, cows, and calves (assumed to weigh on the average 600 lb.); 944,888 sheep and lambs (assumed to weigh on the average 100 lb.); 4,917,631 cwt. of hams and bacon; and 812,237 cwt. fresh and salted beef.

† 638,995,600 in number, each egg being estimated at 2 oz.

‡ Artificial manures are partly prepared from imported phosphates, partly from English coprolites dug out of the ground. They also include "*sulphate of ammonia*" from gas-works, "*nitrate of soda*" from Peru, and potash salts from Germany and from certain manufactures from sea-water and sea-weeds. They are included amongst the imports, because not one particle of them comes out of British soils under cultivation. The estimate of half-a-million tons per annum is under the actual quantity, and their percentages of nitrogen, &c., are certainly not over-estimated.

Exports from United Kingdom in 1879.

Articles.	Cwt.	Containing per cent of— Nitrogen.	Phosphoric Anhydride.	Potash.	Total Quantities exported in Cwt. Nitrogen.	Phosphoric Anhydride.	Potash.
Cheese,	14,231	4.0	0.3	0.5	569	43	71
Horses* and colts (5018),	35,126	3.0	1.8	0.3	1,054	632	105
Guano,	364,180	8.5	15.0	2.0	30,955	54,627	7,284
Rice,	3,288,323	0.98	0.17	0.6	32,226	5,590	19,730
Grain and flour,	1,329,968	1.75	0.8	0.5	23,274	10,640	6,650
Flax and rape seed,	426,990	3.4	1.1	0.9	14,518	4,697	3,843
					102,596	76,229	37,683
Imports,					3,322,537	3,039,041	937,640
Exports,					102,596	76,229	37,683
Balance in favour of Imports,					3,219,941	2,962,812	899,957

* Assumed to weigh 7 cwt. each.

There are 77,513,585 acres in the United Kingdom, of which about 11½ millions of acres are under corn crops, 5 millions under green crops, and 7 millions under rotation grass and clover crops. If we assume that each acre loses annually 9 lb. of nitrogen, 7½ lb. of phosphoric acid, and 4⅘ lb. of potash (according to the estimate given in p. 238), then the total losses sustained by these 23½ millions of acres would be 211,500,000 lb. of nitrogen, 176,250,000 lb. of phosphoric acid, and 112,800,000 lb. of potash.

If, of the imported articles enumerated in the table, we assume that only the nitrogen, phosphoric acid, and potash of the agricultural seeds, oil-cakes, guano,* and artificial manures, were received in 1879 by the 23½ million of acres under cultivation, then their soils must have received 83,396,768 lb. of nitrogen, 207,856,844 lb. of phosphoric anhydride, and 21,796,044 lb. of potash.

Although these figures are mere approximations to the actual numbers, yet we may safely infer from them that the soils of the United Kingdom receive in the form of imported agricultural seeds, manures, and feeding-stuffs, more phosphoric acid than they lose in the produce removed from them. On the other hand, they receive from these sources not much more than two-fifths of the nitrogen, and one-fifth of the potash, which are carried off in produce. To what extent these deficits in nitrogen and potash are supplied by the use of nitrate of soda, soot, town manure, and by the local consumption of imported foods other than those already referred to (including Indian-corn, locust-beans, &c., for cattle), it is difficult to form

* Deducting the exports of guano.

even a conjecture. It would, however, seem evident, that whilst more nitrogen is removed from the soil than phosphoric acid, far more phosphoric acid is returned to the soil in the form of manure than nitrogen. May we not reasonably conjecture, seeing how rich soils are in nitrogen, that there are modes of restoring nitrogen to them which we have not yet discovered? (p. 238.)

Rotation of Crops.—The experiments of Lawes and Gilbert show that soils become exhausted of certain of their constituents sooner than of others. The substance which disappears soonest in the case of certain kinds of cropping is nitrogen (ammonia); but there are other crops which deal gently with the nitrogen, and draw largely upon some of the mineral ingredients of the soil. During the growth of leguminous crops, nitrogen accumulates in the surface-soil.

If two crops of unlike kinds be sown together, their roots suck in the inorganic substances in different proportions—the one more potash and phosphoric acid perhaps; the other more lime, magnesia, or silica. They thus interfere less with each other than plants of the same kind do—which require the same kinds of food in nearly the same proportions.

Or the two kinds of crop grow with different degrees of rapidity, or at different periods of the year: while the roots of the one are busy drawing in supplies of inorganic nourishment, chiefly from great depths, those of the other are only able to take up food from the surface-soil.

If each crop demands special substances, or these substances in quantities peculiar to itself, or in some peculiar state of combination, the chances that the soil will be able to supply them are greater, the more

degrees, just as it is wanted, to the shoot or to the root. The starch, when thus changed and rendered soluble, becomes the substance called *dextrin*, which we have already described (p. 70). In the oily seeds which contain no starch, the mucilage and the oil take the place of starch in nourishing the young sprout. The results of the experiments of Fleury and Sachs seem to indicate that in oily seeds dextrin and sugar are formed by the oxidation of the fats.

As the sap ascends it becomes sweet—the dextrin formed from the starch is further changed into sugar. When the shoot first becomes tipped with green, this sugar again is changed into cellulose, or woody fibre, of which the stem of perfect plants chiefly consists. By the time that the food contained in the seed is exhausted—often long before—the plant is able to live by its own exertions, at the expense of the air and the soil.

This change of the sugar of the sap into cellular or woody fibre is observable more or less in all plants. When they are shooting fastest the sugar is most abundant—not, however, in those parts which are actually shooting up, but in those which convey the sap to the growing parts. Thus the sugar of the ascending sap of the maple and the alder disappears in the leaf and in the extremities of the twig; and the sugar-cane *sweetens* only a certain distance above the ground, up to where the new growth is proceeding: and thus also the *young* beet and turnip abound most in sugar,—while in all these plants the sweet principle diminishes as the year's growth draws nearer to a close.

In the ripening of the ear, also, the sweet taste at

first so perceptible in young grain gradually diminishes, and finally disappears. The sugar of the sap is here changed into the *starch* of the grain, which, as above described, is afterwards destined, when the grain begins to sprout, to be reconverted into sugar for the nourishment of the rising germ.

In the ripening of fruits a different series of changes presents itself. The fruit is at first tasteless, then becomes sour, and at last sweet. In this case, either the acid of the unripe, is changed into the sugar of the ripened, fruit, or a portion of the other constituents of the fruit is converted into sugar and disguises the acid.

Does Light affect Germination.—It is a popular notion that seeds require to be protected from the action of light if it be intended that they should germinate. In nature, however, we find the seeds simply scattered over the surface of the soil, and fully exposed to light. The experiments of Hoffmann and other investigators have, moreover, proved that various kinds of seeds (all that were experimented with) freely germinated in the light. On the other side, Hunt, many years ago, stated, as the result of his experiments, that luminous rays prevent the germination of seeds.

Influence of Heat on Seeds.—It has been found that seeds do not germinate below 37° Fahr., or at a higher temperature than about 128° Fahr. They retain their vitality at very low temperatures, but when heated above 168° Fahr. they are, with rare exceptions, killed. Seeds which were left within the Arctic circle by an exploring expedition, and were some years subsequently brought to England (by the North

Pole Exploration Expedition) in October 1876, germinated freely.

It is stated by Sachs that the best plants are produced when germination has taken place at medium temperatures—from 20° to 30° Centigrade (68° to 86° Fahr.)

Moisture necessary to Germination.—Seeds cannot germinate without water, but the requisite amount of this liquid varies according to the nature of the germ. In the case of the agricultural plants, germination is best effected when the soil is *moist*, but not *wet*.

Some seeds absorb during germination very large quantities of water, whilst others take up minute amounts. Thus R. Hoffmann found that mustard seeds absorbed 8 per cent, and white clover seeds, 126.7 per cent, of water during germination. The seeds of the ordinary cereals take up about half their weight of water; whilst the seeds of grasses and legumes take up their own weight of moisture.

Hastening Germination.—Many suggestions have been made with the object of hastening and promoting germination. According to Böttger, this object is accomplished by the application of a moderately strong solution of potash or soda to the seeds. Weak solution of chlorine gas in water has been also recommended. It is alleged that camphor has a wonderful influence in favouring the germination of seeds, and that, unlike turpentine, which has been employed for the same purpose, it is never, even when used in excess, hurtful. The latter assertion is doubtful.

Proper Depth of Sowing.—Seeds should not in these climates be sown deeply. Hoffmann found

that the seeds of 24 kinds of plants cultivated by farmers and market-gardeners perished when placed 12 inches below the surface. The depth at which seeds are best sown depends to some extent upon climate and soil; but, as a rule, the proper depth is from 1½ to 3 inches.

Gases exhaled during Germination.—It is a curious fact that seeds do not germinate in pure oxygen gas; but if exposed to a mixture of 4 parts of hydrogen and 1 of oxygen (air being composed of 4 of nitrogen and 1 of oxygen) they germinate freely. Carbonic dioxide is evolved in considerable quantity from germinating seeds, and oxygen is absorbed. It is asserted by Déhérain and Landrin that nitrogen is exhaled also, but only in an early stage of germination. Leclerc denies the accuracy of this statement, maintaining that any nitrogen which may be evolved during germination is merely a product of the decomposition of ungerminated seeds.

Malting Grain.—The *malting of grain consists* simply in germinating seeds of barley, &c., and allowing the development of the embryo plants to go on for a certain time, when they are killed by the application of heat. In germinating grain there is developed a small quantity of a white, insipid, nitrogenous substance termed *diastase*. This compound is a ferment, and it possesses the property of causing starch, which is naturally insoluble, to ferment and become soluble —*i.e.*, by being changed into dextrin and sugar. When the seeds have partly germinated, further chemical change in their composition is prevented by simply killing the embryo plants. This is effected by heating them up to a temperature of from 145° to

164° Fahr., according as the malt is required to be light or dark in colour. It is stated that one part of diastase is capable of converting 2000 parts of starch into sugar and dextrin. Payen and Persoz state that at 75° Cent. (167° Fahr.), diastase loses its property of rendering starch soluble; when, therefore, malt is intended for the brewer, or even as an addition to food for cattle, care should be taken not to heat it up to 167° Fahr. A large amount of diastase formed during germination remains until the last stage of the process. It is this excess of diastase which enables the distiller to ferment molasses or starch, or unmalted corn, by mixing them with from 10 to 50 per cent of malted grain.

According to Dubrunfaut, a nitrogenous ferment, which he terms *maltin*, exists in malted barley, and in all cereal grains. It is much more active than diastase; and Dubrunfaut suggests that the latter is probably only a product of the decomposition of the former.

Conclusion of Germination.—When the embryo contained in the seed has become developed into a young plant it will be found that all the provisionary stores of food accumulated by the parent, and disposed in close contiguity with its offspring (in embryo) have become exhausted. The young plant is now, however, possessed of leaves and a root, and with these organs it at once commences to absorb nutriment from air and soil.

CHAPTER XXII.

THE ASSIMILATION OF CARBON, OXYGEN, AND HYDROGEN BY PLANTS.

Oxygen, hydrogen, carbon, and nitrogen, are always found in every plant and animal; and as they constitute the great bulk of organic bodies, they have been termed the *organic* elements. These elements do not appear to be capable of direct absorption by plants; but in combination they are always present in the air and soil, and furnish plants with by far the greater portion of their food.

Absorption of Carbonic Dioxide.—This gas is absorbed only when the plant is exposed to light, and especially to direct sunlight. In the dark, oxygen is absorbed and carbonic dioxide is exhaled, which indicates that a portion of the plant is oxidised when light is absent. The changes which carbonic dioxide undergoes whilst in the wonderful vegetable laboratory, are not thoroughly understood. We know that a large portion of its oxygen is separated from it, and evolved in a pure state into the atmosphere. The influence of light in enabling plants to absorb and decompose carbonic dioxide has been conclusively proved by numerous experimenters, but by none more strikingly than by Boussingault. He found that a bean seed weighing 0.922 gramme (a gramme is nearly 15½ grains) became in twenty-five days a plant which weighed (when dried) 1.293 grammes, being an increase in its weight of 0.371 gramme

This increase consisted of 0.1926 gramme of carbon, 0.02 gramme of hydrogen, and 0.1591 gramme of oxygen. At the same time another seed of a bean grown under similar conditions, save complete exclusion of light, declined in weight from 0.926 gramme to 0.566 gramme; the loss of 0.360 gramme consisted of 0.1598 gramme of carbon, 0.0232 gramme of hydrogen, and 0.1766 gramme of oxygen. Macagno found the absorption of carbonic dioxide by plants was greater when they were placed in white light than in coloured lights.

The following table shows the relative extent to which beans increased when exposed to different coloured lights during three weeks.

RELATIVE INCREASE OF BEANS IN DIFFERENT COLOURED LIGHTS.

	Organic Matter.	Ash.
White light,	0.452	0.082
Violet,	0.278	0.052
Red,	0.189	0 075
Yellow,	0.168	0.054

The amount of carbonic dioxide in pure air is only 0.035 per cent. An increase of this proportion is found to be beneficial to plants. According to Godlewski, the maximum amount of carbonic dioxide which he found to be beneficial to Glycerea was from 8 to 10 per cent; a larger proportion proved injurious. Some plants would, no doubt, be injured by exposure to air containing even 8 per cent of carbonic dioxide.

Böhn in his experiments found that more than 2 per cent of carbonic dioxide is injurious to plants, and that 20 per cent kills them.

The action of light in enabling plants to deoxidise carbonic dioxide is exerted chiefly in their green, or chlorophyll-holding, organs. C. Kraus suggests that chlorophyll decomposes carbonic dioxide into carbonic monoxide and oxygen $= CO_2 = CO + O$. The carbonic monoxide thus formed, combining with water, produces a carbo-hydrate, of the formula $= C_6H_{12}O_6$. This carbo-hydrate by losing water would form pyrocatechin, the liberated oxygen at the same time oxidising other carbohydrates into acids. The following equation represents the possible transformation of grape-sugar into oxalic acid :—$2C_6H_{12}O_6 + 9O_2 - 6H_2O = 6C_2H_2O_4$.

It is supposed that carbonic dioxide and water may under the influence of light react upon each other in the following manner :—$5CO_2 + 5H_2O = 10O + C_5H_{10}O_5$ (starch). These are, however, only plausible conjectures as to the manner in which carbonic dioxide and water are converted into organic compounds.

Assimilation of Oxygen and Hydrogen.—Plants do not possess the power of absorbing, or at least of assimilating, the free oxygen and hydrogen gases which surround them so abundantly. Water supplies them with oxygen and hydrogen, whilst the latter element is also obtained by them in small quantity from ammonia (NH_3). In the soil there are various kinds of organic bodies, containing oxygen and hydrogen, and soluble in water. It is a vexed question whether or not these soluble organic matters are taken up by plants, and used as food by them.

The plant that grows on the surface of common vinegar, and makes it thick and glairy, is formed from the vinegar itself (pure vinegar, like starch

and cellular fibre, consists of carbon and the elements of water alone ($C_2H_4O_2$), 24 of carbon and 36 of water forming 60 of vinegar by weight) and from a nitrogenous substance resembling gluten which the liquid vinegar holds in solution. So the mould which grows on flour-paste is formed from the starch and the gluten of the flour; and the minute plant which forms the yeast in the brewer's vat is produced from the sugar of the wort and the changed gluten of the barley.

In all these cases the substance of the plant is formed by the direct appropriation of compounds, which bear a close analogy to those of which its own parts consist; and though the mould-plants above mentioned are very different in kind from those we raise for food, yet the mode in which they are built up is very similar to that by which the solid parts of larger plants are really produced from the substances contained in the sap. If, then, those substances from which their growing parts are thus known to be built up can be conveyed directly into the circulation of our cultivated plants by their roots, are we to conclude that their growth may be promoted by *them* at least as well as if the roots took up only carbonic acid to supply the carbon and ammonia to supply the nitrogen?

It must, however, be borne in mind, that moulds are parasitical plants living wholly upon the organic matters elaborated by other kinds of plants of a totally different mode of growth. The parasitical plants die if they are deprived of their organic food, although they may be abundantly supplied with carbonic dioxide, water, and ammonia. On the other hand,

ordinary plants probably would soon perish if restricted to organic substances as sources of their nutriment. If soluble organic matter were really capable of being assimilated by plants, such substances as nitrate of quinine, rich in nitrogen, should be sources of that element to plants. Ville's recent experiments show, however, that only the most simply constituted nitrogenous bodies are capable of being absorbed by plants. For example, urea is assimilable, oxamide is not assimilable.

Ammonia is composed of an atom of nitrogen, combined with three of hydrogen. Its molecule is composed of $\left.\begin{matrix}H\\H\\H\end{matrix}\right\}N$; a double molecule of ammonia is therefore constituted as follows :— $\left.\begin{matrix}HH\\HH\\HH\end{matrix}\right\}\begin{matrix}N\\N\end{matrix}$

Now, each of these atoms of hydrogen may be replaced by a great variety of substances giving rise to numerous substitution compounds. Thus when CO replaces HH, we have $\left.\begin{matrix}HH\\(CO)\\HH\end{matrix}\right\}\begin{matrix}N\\N\end{matrix}$ = Urea. Ethyl (C_2H_5)—the basis of alcohol—replaces another atom of hydrogen, forming ethyl-urea = $\left.\begin{matrix}(C_2H_5)H\\(CO)\\HH\end{matrix}\right\}\begin{matrix}N\\N\end{matrix}$

Ville states that plants can assimilate the substances termed urea and ethyl-urea, because they are comparatively simple in structure, and are produced by replacing a portion of the hydrogen of ammonia by the radicles CO, and C_2H_5 and CO. If, however, four atoms of hydrogen in the double molecule be

replaced, the substance becomes too much organised to be assimilable by plants. The substance termed diethyloxamide $= \left.\begin{matrix} C_2O_2 \\ (C_2H_5)_2 \\ HH \end{matrix}\right\} \begin{matrix} N \\ N \end{matrix}$ is wholly inert.

Many chemists are in favour of the view that animal or vegetable substances containing nitrogen, when brought into a soluble state by fermentation, may enter directly into plants, though they are not usually assimilated without being first *decomposed* either into ammonia or into nitric acid. Thus A. Stutzer states * that tartaric and citric acids (especially when in combination with calcium) furnished carbon to plants which were grown in air free from carbonic acid. He proved, however, that the acids were first oxidised into carbonic acid, which, being assimilated by the plants, produced carbo hydrates. Dilute solutions of oxalates also furnished, in the same way, carbon to water-plants. Insoluble acetates and succinates also furnish carbon to plants, but not so effectively as the tartrates. Stutzer concludes that the tartaric and oxalic acid groups which contain carboxyl (the oxatyl of Frankland), $= HCO_2$, cannot be directly assimilated by plants; but that the alcohol groups of tartaric acid, which are of simpler constitution, may directly furnish nutriment to plants. Schmoeger, however, states that in his experiments the oxalates and tartrates only nourished plants by furnishing carbonic acid (*Berichte der Deut. Chem. Ges.*, 12, 753-758).

Plants cannot assimilate matter in a highly organised form, but certain substances which, though

* Berichte der Deutschen Chemischen Gesellschaft zu Berlin, 1876, p. 1395.

organic, are very analogous to mineral substances, may contribute directly to the nourishment of plants.

CHAPTER XXIII.

THE ASSIMILATION OF NITROGEN BY PLANTS.

The amount of nitrogen in plants is not less than 1¾ per cent, and this gas constitutes about four-fifths of the weight of the atmosphere; yet it is most likely that plants cannot utilise the most minute proportion of the unlimited supplies of nitrogen which surround them. For many years the question, Can plants assimilate free nitrogen? was discussed by many distinguished agricultural chemists.

In 1849-52, M. G. Ville, of Paris, made some experiments, from the results of which he concluded that plants absorb free nitrogen as well as ammonia and nitric acid. He supplied plants in closed vessels with air free from ammonia, or with air in which the amount of ammonia was known, and he found that the plants increased in nitrogen to a much greater extent than could be accounted for otherwise than by absorption of free nitrogen.

In 1855, a commission, consisting of Dumas, Regnault, Payen, Decaisne, Peligot, and Chevreul, superintended a repetition of Ville's experiments, and reported that their results confirmed his previous statement.

De Luca, in 1856, suggested that as the oxygen given off by plants was often in the form of ozone (highly active oxygen), the latter might convert the free nitrogen of the air into nitric acid, which then would afford nitrogen to plants. The previous year Cloez had suggested that nitrogen might be converted into nitric acid by contact with alkaline bodies and porous substances.

Roy, in 1854, advanced the theory that plants are unable to take in free nitrogen through their leaves, but that they can absorb it by their roots from its solution in water.

We shall now give a brief summary of the evidence which has been given for the other side of this question. Nearly a century ago Sennebier and Woodhouse came to the conclusion, from the results of experiment, that free nitrogen was unassimilable by plants. Late in the last century, and in the beginning of the present one, the distinguished agricultural chemist, De Saussure, made numerous experiments, from the results of which he concluded that the nitrogen of plants was obtained, not from the free gas in the air, but from soluble organic matters contained in the soil, and from atmospheric ammonia.

In 1837, Boussingault commenced an investigation into this matter, which, for more than twenty years subsequently, he worked out with all his accustomed skill and accuracy. His results were diametrically opposite to those arrived at by Ville. He found that plants did not assimilate free nitrogen, either when utterly deprived of other sources of that element, or when they were supplied with it in combined forms.

Mené in 1851, and Hartig in 1855, published the

results of experiments on the assimilation of nitrogen by plants, which were adverse to Ville's conclusions.

The most elaborate and, in our judgment, the most conclusive contribution to the elucidation of this question are the experimental results of Messrs Lawes, Gilbert, and Pugh, published in the transactions of the Royal Society, part ii., 1860. In this elaborate memoir the experiments of all previous investigators are examined, criticised, and in many instances repeated. The original experiments devised by Messrs Lawes, Gilbert, and Pugh, were carried out with the most minute attention to details, and with every precaution against error. The results confirm those of Boussingault, and disprove Ville's conclusions.

Nitric Acid a source of Nitrogen.—One of the most abundant sources of the nitrogen of plants is nitric acid. This substance is found in the juices of plants, especially those of a fleshy, tuberose character. It exists in the soil, and is found largely, as we have shown in the chapter on drainage, in the water which flows through the soil. It is formed by the oxidation of ammonia; and many chemists believe that it is nitric acid and not ammonia which is the chief contributor of nitrogen to vegetation.

In the sap, nitric acid will at first exist as potassic, or other, nitrate. Emmerling suggests that these nitrates are most likely decomposed by the oxalic acid, or the acid oxalates, which undoubtedly exist in plants. The nitric acid thus set free might, by uniting with carbonic compounds, produce albuminous substances or their groundwork. Oxalic acid appears to be a final product of vegetable life.

Cyanogen (CN) in the form of potassic or sodic

sodium is thirty times more abundant than potassium, yet in sea-weeds the two metals exist in about the same relative proportions. In *Laminaria latifolia* Schwitzer found 16.91 per cent of potash, and 10.18 per cent of potassic chloride, as against 26.92 per cent of sodic chloride. Gödechaus found an average of 30 per cent of potash and potassic chloride in sea-weeds. In fourteen analyses of these plants made by Forchammer, sodium and potassium were equally abundant, whilst Anderson found more potash than soda in them. Cadet grew a soda-loving plant, namely, *salsola kali*, in garden soil. The plants produced contained both potassium and sodium; but the seeds obtained from these plants when sown in the same soil developed into plants in which no sodium was present, but, on the contrary, a very large proportion of potassium. It has been found that many plants which usually grow at the sea-coast, and in which sodium compounds are abundant, contain little or none of that element when found in inland situations. Potassium, on the contrary, is always present in plants, no matter where they may be grown.

Is Sodium essential to Plants?—Sodium (Na) is found in great abundance in marine plants, chiefly as carbonate and chloride. It is largely present in the ash of the mangel-wurzel. There is some reason, however, to doubt its essentialness to any kind of vegetable, though it would appear as if it sometimes *partially* replaced potassium. In the earlier analyses of the ash of plants, sodium appears always to have been found, and generally in large quantity. Thus, Sprengel estimated 38 per cent of soda in the ash of the bean, whilst Richon found only 19, and Levi 12

per cent, in the same kind of seed. Boussingault, in comparatively modern times, detected no sodium at all in the pods of haricots (French beans); and Way and Ogston found only 2.8 per cent of soda in ordinary beans. Sprengel found 20 per cent of soda in peas, whilst Boussingault, Erdmann, and Rammelsberg found no soda in them. In potatoes, soda has not been detected by two observers;* by others it has been found only in small quantities.

In 1867, Peligot devised an improved method of separating potash from soda, and used it in determining the amount of soda in plants. He found this substance absent from a great number of plant-ashes; for example, from the following: wheat and oats (straw and grain), potatoes (tubers and stalks), beans, parsnips, spinach, vines, tobacco, mulberry, and castor-oil beans. In mangels and some other plants, soda was found, but in even these potassium salts predominated. H. Hoffmann grew plants which are usually regarded as "soda-loving," in soils free from soda, and apparently without any detriment to the plant.

Sodium is indispensable to animal life. Perhaps the reason why animals instinctively desire and relish common salt (sodic chloride) is because it might not be always or generally supplied to them in vegetable food. Animals have not the same longing for potassic chloride, or calcic phosphate, substances equally indispensable to them as sodic chloride, but certain to be adequately supplied in vegetable food.

Calcium (Ca) **and Magnesium** (Mg) **in Plants.**—The metals calcium and magnesium are important and indispensable constituents of plant-ashes. The

* Metzdorf and C. A. Cameron.

former is generally in by far the larger proportion in the succulent parts of plants. In the seeds of wheat, oats, and other plants, magnesia (MgO) usually preponderates over lime in the proportion of about 7 to 2. In the stems (straws) of the cereals, lime is nearly three times more abundant than magnesia. In root-crops lime exceeds magnesia in quantity. In plants, calcium and magnesium exist as phosphates and carbonates, and also as constituents of such organic salts as calcium oxalate, &c. Phosphates, carbonates, and sulphates of magnesium and calcium occur in soils, and occasionally magnesium and calcium chlorides. Plants, therefore, seldom fail to find adequate supplies of these metals.

Aluminium (Al).—In the ashes of certain *lycopods* or "club-mosses," aluminium has repeatedly been detected; and by one analyst, Professor Church, in considerable quantity. It is, however, not always to be met with in the lycopods, and it has very rarely been observed in any other plants. It is highly probable, therefore, that this metal is not essential to vegetable life, neither is it to animal existence.

Iron (Fe) **in Plants.**—If iron be carefully sought for in a whole plant, it will certainly be found, though generally in very minute quantity. In the ashes of certain plants ferric oxide (Fe_2O_3) has, however, been found to the extent of from 2 to 7 per cent, but in general it is under 1 per cent. It is asserted that plants which were blanched, and otherwise exhibited a sickly appearance, were rendered green and healthy by the application of a very weak solution of an iron salt.

Manganese (Mn) is very frequently found in minute quantity in plant-ashes. According to the Prince

of Salm-Horstmar, it is indispensable to vegetation; but this is denied by other observers. Manganese is generally associated with iron, and one of its oxides (Mn_2O_3) resembles ferric oxide; Birner and Lucanus found that Mn_2O_3 could not replace Fe_2O_3 in vegetables. Kane detected 1 per cent of Mn_2O_3 in flax, and Ruling estimated 4 per cent of this oxide in the ash of the sweet flag, whilst it was detected to the enormous extent of 11.2 per cent in beech-ashes by Fresenius. At present it is impossible to pronounce a correct opinion as to the essentialness of manganese as an ingredient of plants.

Silica, or Silicic Dioxide (SiO_2), constitutes no inconsiderable proportion of the external layers of the stems and leaves of the cereals; it makes up about 60 per cent of the weight of the ashes of straw, and 35 per cent of the inorganic portion of the grasses. In other plants, and in seeds, it is a somewhat scarce substance. Grave doubts have been raised as to the essentialness of silica as a plant-food. Knop and Sachs grew artificially maize-plants from which the silica was, save an almost inappreciable trace, rigorously excluded. The plants were healthy and produced seeds. Other experimenters of repute—Nobbe and Siegert, Stohman, Wolfe, &c.—have produced oats, maize, and buckwheat containing no silica; and Pierre has demonstrated that the weakness sometimes observable in the stems of the cereals is not attributable to a deficiency of silica.

It may be that silica is not indispensable to plants, though it is very remarkable that so large a proportion of this substance should occur in so many of them. Perhaps the silica found in plants had been associated

with potash, and taken up into the vegetable, not because the latter required silica, but because it stood in need of the potash. If the potash were appropriated, then the silica being insoluble would be mechanically retained in the tissues of the vegetable. It has been found that plants grown in solution of ammonic chloride have appropriated the ammonia of the salt, and set free the chlorine combined with hydrogen ($NH_4Cl = NH_3 + HCl$). A similar reaction is quite possible in the case of potassic silicate.

Chlorine (Cl) is taken up into plants chiefly in the form of common salt and chloride of potassium. It is not abundant in the cereals, is present in decided quantity in turnips, mangels, and similar plants, and is contained in large proportions in sea-coast and marine plants. Opinion is divided as to the essentialness of chlorine to plants. It is certain that chlorine is always present in vegetables grown naturally; but it is probable that, if necessary to them, it is only required in very small quantity.

Sulphuric Acid (H_2SO_4).—Calcic sulphate ($CaSO_4$) is probably the chief source of the sulphuric trioxide found in plants, and which, without doubt, is absolutely essential to their growth. SO_3 (sulphuric anhydride) constitutes from 2 to 7 per cent of the ash of plants.

Phosphoric Pentoxide (P_2O_5). — Phosphates of different bases exist largely in vegetable ashes. In some the amount of magnesic and calcic phosphates reaches 60 per cent. No one doubts the importance of the phosphates to vegetable life.

Fluorine (F) is found in the teeth and other bones of animals, and is therefore in all probability derived from vegetables, which directly or indirectly exclu-

sively furnish the nutriment for animals. It is certain that water does not, as a rule, contain fluorine. Fluorine is therefore probably essential to plants, but no doubt a very minute quantity of it is sufficient for their wants.

Iodine (I), **Bromine** (Br), **Copper** (Cu), **Lead** (Pb), **Lithium** (Li), **Cæsium** (Cæ), **and Rubidium** (Rb), although occasionally found in plants, are in all probability merely accidentally present.

CHAPTER XXV.

THE COMPOSITION AND DISTRIBUTION OF THE ASH CONSTITUENTS OF PLANTS.

Percentage of Ash in Plants.—The percentage of ash in the dry matter of plants (that obtained by drying the plants at a temperature of 212° Fahr., until they cease to lose weight) is usually from about 3 to 6 per cent of the entire plant. In the seeds the amount of ash is generally very small; but in the leaves it often amounts to more than 20 per cent. In the following table the average percentage of ash in various vegetable products is shown:—

SEEDS.

Wheat grain,	1.9	Indian corn,	1.5
Oat "	2.9	Bean,	3.6
Barley "	2.2	Peas,	2.7
Rye "	2.6		

STEMS.

Wheat straw,	5.0	Rye straw,	5.2
Oat "	5.4	Bean "	8.0
Barley "	6.7	Pea "	6.2

ROOTS AND TUBERS.

Potato,	4.3	Carrot,	8.0
Mangel,	8.5	Kohl rabi,	8.0
Swede,	11.0	White turnip,	6.0
Turnip,	10.0	Parsnip,	6.2

WHOLE PLANTS.

Red clover,	6.8	Wheat,	4.6
White clover,	7.3	Flax,	4.3
Oats,	5.2	Gorse or furze,	7.0
Hemp,	4.5	Cabbage,	8.0

WOODS.

	Wood.	Leaves.	Seed.
Willow,	0.45	0.82	0.33
Beech,	1.4	0.42	...
Birch,	0.3½	0.50	...
Pine,	0.3	0.20	0.50
Elm,	0.19	0.120	

It appears, therefore, that by far the larger proportion of the inorganic matter which is withdrawn from the soil by a crop of corn is returned to it again, by the skilful husbandman, in the fermented straw. In the same way also nature, in causing the trees periodically to shed their leaves, returns with them to the soil a very large portion of the soluble inorganic substances which had been drawn from it by their roots during the season of growth.

Thus an annual top-dressing is naturally given to the land where forests grow; and that which the roots from spring to autumn are continually sucking up, and

carefully collecting from considerable depths, winter strews again on the surface in the form of decaying leaves, so as, in the lapse of time, to form a rich and fertile soil. Such a soil must be propitious to vegetable growth, since it contains or is made up of those very materials of which the inorganic substance of former races of vegetables had been almost entirely composed.

Wolff states that the average amount of ash in cereal (fresh) grain is 2 per cent, and in their stems 5 per cent. In the leguminous crops the ash makes up 3 per cent of their seeds, and 4.5 per cent of their leaves.

A crop of 8 tons of potato-tubers per acre removes about 180 lb. of mineral matters, of which about one-half consists of potash, and one-ninth part of phosphoric acid. A mangel crop weighing 20 tons of roots per acre removes from the soil (excluding the amount taken up in foliage) from 300 to 380 lb. of mineral matter, including from 100 to 140 lb. of potash, and from 15 to 25 lb. of phosphoric acid. Cereal crops remove only about 85 lb. of mineral matter per acre, of which 10 or 12 lb. consist of potash, and 14 or 15 lb. of phosphoric acid.

Variability of Plant-ashes.—The ash of each of our cultivated plants has been, as a rule, repeatedly examined, and by different chemists. Their results have not generally been very close, and occasionally they have been almost discordant. In the case of particular kinds of plants, one chemist has found magnesium to preponderate in quantity over calcium; whilst in examining the same kinds of vegetables another analyst has found an excess of calcium over magnesium. Chlorine, silica, ferric oxide, and sulphuric trioxide, have been detected by some chemists

COMPOSITION PER 100 PARTS OF THE ASH OF PLANTS (EXCLUDING CARBONIC DIOXIDE)—*continued.*

	Cow cabbage leaves.	Carrot root.	Wheat straw.	Oat straw.	Barley straw.	Pea straw.	Red clover hay.	Meadow hay.	Grasses in Flower.		
									Bromus erectus.	Solium perenne.	Annual rye-grass.
Potash (K_2O), . .	34.85	41.46	12.16	20.60	19.32	22.00	31.86	26.80	25.92	30.79	27.07
Soda (Na_2O), . .	4.60	17.60	1.00	6.00	4.50	6.00	2.16	5.80	0.50	9.90	2.87
Magnesia (MgO),	4.40	5.36	4.00	3.66	2.70	7.34	12.16	4.32	4.80	8.25	2.59
Lime (CaO), . .	19.60	8.86	6.82	8.10	7.00	39.00	31.09	12.86	10.20	3.00	6.82
Ferric oxide (Fe_2O_3),	0.17	0.32	1.02	0.83	0.26	1.08	0.66	0.76	0.23	trace	0.28
Phosphoric anhydride (P_2O_5),	16.63	12.68	3.20	4.16	4.83	6.84	9.00	6.95	8.00	9.00	10.07
Sulphuric anhydride (SO_3),	17.31	6.93	5.78	13.32	3.78	6.30	3.03	4.45	5.42	5.20	3.45
Silica (SiO_2), . .	2.44	2.00	65.34	50.08	56.85	6.18	6.71	31.04	38.10	21.56	41.79
Chlorine (Cl), . .	trace	4.79	0.60	3.25	0.76	5.26	3.33	7.02	6.83	17.30	3.06
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

In the earlier analyses of vegetable ashes, the amount of soda is generally stated in higher figures than we find in the modern analyses of the same substances. In several of the statements of the analyses of beans and other plants used in preparing the table, no mention whatever is made of soda.

Causes of Variations in the Ash.—There are obvious reasons why analyses of any kind of plant must differ in their results. The composition of plants, like that of animals, but to a far greater extent, differs at different periods of their growth. A large excess of soluble mineral matters in the soil is probably the cause of a large amount of these substances being present in the plants grown upon it. Healthy plants have the power of absorbing a greater quantity of soluble inorganic matter than weakly ones. The eminent agricultural chemist, Arendt, found the following differences in the composition of healthy and weakly oat plants :—

	Potash and soda.	Lime.	Magnesia.	Ferric oxide.	Phosphoric acid.	Sulphuric acid.	Silica.	Chlorine.
Luxuriant oat plants,	45.30	6.1	2.9	0.4	8.2	4.8	27.	6.7
Strong oat plants, .	34.3	5.4	2.3	0.5	8.5	4.1	39.9	5.8
Weakly oat plants, .	30.4	5.2	2.3	1.0	8.8	5.6	42.0	4.7

The Proportion and Nature of Ash vary during Growth.—The composition of the organic and mineral constituents of plants varies during their growth. In the clovers, the proportion of ash ingredients diminishes as the plants grow older. When the plants are

young, their stems and leaf-stalks are very rich in inorganic matter; but at the period of flowering, the ash decreases in the stems and increases in the leaves. Potash abounds in the stems and lime in the leaves—increasing therein until the flowering of the plant is perfected. Phosphoric acid is at first abundant in the leaves, but ultimately it accumulates chiefly in the blossoms. Silica remains all through in the stems and leaves; whilst chlorine, which at first abounds in the stems and leaves, migrates subsequently in great part to the blossoms.

Bretschneider analysed specimens from an oat crop at different periods of their development. 1st, 19th June, fifty-eight days after sowing; 2d, 29th June, when the ears had just left their sheaths; 3d, 8th July, when the crop was in full bloom; 4th, 28th July, when the plants were beginning to ripen; 5th, 6th August, when the crop was fully ripe. The composition of the ash at four of these stages is shown in the following table:—

COMPOSITION OF OAT-ASH AT DIFFERENT PERIODS OF THE PLANT'S DEVELOPMENT.

	1	2	3	4
Potash,	28.96	25.60	25.90	19.14
Soda,	6.40	8.67	4.16	5.29
Lime,	5.66	6.46	5.19	5.43
Magnesia,	5.34	5.25	4.98	5.02
Ferric oxide,	1.22	0.39	0.31	0.39
Phosphoric acid,	7.95	9.17	9.61	10.13
Sulphuric acid,	5.57	2.46	1.99	3.89
Silica,	36.28	40.00	45.57	49.17
Chlorine,	3.38	2.58	2.94	2.00
	100.76	100.58	100.75	100.46

The oat assimilates little, if any, phosphoric acid, or magnesia, after blossoming. The leaves are rich in silica, which accumulates in the upper leaves after the plant has put forth its blossoms. It is worthy of note that the leaves of the oat are richer in silica than the stem. It has been observed that where ammonic chloride is given largely to plants, its ammonia is assimilated to a greater extent than its chlorine, and the latter is rejected in the form of hydrochloric acid —$NH_4Cl = NH_3$ (ammonia), and HCl (hydrochloric acid). It may be that silica is taken up into plants in the form of potassic silicate, not because the plant wants silica, but because it requires potash. Silica thus introduced into plants would probably remain in their tissues owing to its insolubility. Phosphoric acid and magnesia attain to their maximum amounts in the ear.

Dr Anderson found that turnips, examined at four different periods from July 7th to October 6th, yielded the following percentages of ash in (dried quantities) root and leaves: Roots, 17.7, 8.7, 10.2, 20.97; leaves, 7.8, 20.6, 18.8, 16.2. Here we find the ash decreasing during nearly the first half of the growth of the root, and then increasing to more than the original amount. On the other hand, the leaves increased in ash constituents until the plants were about half grown, when the amount of ash decreased by one-fourth during the rest of the growth of the crop.

In this chapter we have shown that the analyses of the ashes of plants do not always agree in the case of the same kind of plant; nevertheless these analyses have established certain broad facts — they have

proved that the variation in the composition of each plant is confined within certain limits, and that there are well-marked differences between the composition of the ashes of many important classes of vegetables.

CHAPTER XXVI.

ON MANURING.

Why Manures are required.—The crops produced upon a farm take out of its soils certain quantities of mineral matters and nitrogen. If the edible parts of the crops be consumed upon the farm, and the solid and liquid *excreta* of the animals fed upon them completely put into the soils, then the soils would increase in fertility up to a certain point. The instances, however, are very rare in which the produce of the land is consumed on the spot, and the products of its decomposition (after reorganisation in the bodies of animals) returned, with the exception of comparatively unimportant gaseous matter, to the soil. A feature of all the systems of agriculture prevalent in civilised countries is, that a large proportion of the animal or vegetable products of the farm is sent away to be consumed at a distance. The (effete) matters into which the products are converted, instead of being returned to the land from which they were obtained, are for the most part discharged into rivers, which convey them into the ocean. The problem then is, How may the farmer continue to send away

the greater portion of the products of his land, and yet maintain the fertility of his soils?

The Mineral Theory of Manures.—Liebig has offered a solution to this problem. He maintains that the fundamental principle of agriculture is the complete restoration to the soil of the mineral matters, or ash constituents, taken out of it by crops. With respect to the nitrogen, he believes that it is chiefly, if not altogether, derived from atmospheric sources—from nitric acid and ammonia. If crops be furnished with ash constituents, they will gather in their supplies of nitrogen from the air. The plants with large leaves, such as the cabbage and the turnip, take up more ammonia from the air than those with small leaves—such as, for example, the wheat and the oat. The plants with large leaves accumulate nitrogen in their foliage and stems to such an extent, that when deposited, as these parts usually are, in the soil, they help to furnish nitrogen to the plants which follow them, and which have less absorbent powers in relation to the gases and vapours in the atmosphere. According to Liebig, fallow increases the fertility of soils by allowing time for the decomposition of alkaline silicates, which would furnish supplies of potash in a soluble form. The rotation of crops is useful,—firstly, because certain of the crops in the rotation accumulate organic matter in the soil; secondly, because particular crops require only small proportions of ash ingredients, which other crops take up in considerable quantities. During the growth of a crop which, for example, requires but little magnesia, that substance accumulates (by decay of rock-materials) relatively to other ash ingredients.

When, therefore, the time for sowing a magnesia-loving crop arrives, that substance will be present in larger quantity than would be the case if another magnesia-loving crop had been grown in the preceding year.

Liebig follows up his theory of manures by suggesting the employment of fertilisers, each of which should contain the mineral substances in such quantities and combinations as they are actually found in the crops to which they are to be applied. The nature of the ash of each crop being accurately ascertained, a manure of the same, or nearly identical, composition, is to be manufactured and applied exclusively to that particular crop. These manures are to consist chiefly of potassic carbonate and silicate, calcic carbonate, phosphate, and sulphate, sodic chloride, ammonic magnesic phosphate, and bone-earth. In none of these manures is the amount of ammonia found to exceed 0.4 per cent. "Mineral manures," prepared according to the suggestions of Liebig, were made patented articles in England and on the Continent, and were at first rather extensively employed. They failed, however, to realise the expectations of Liebig, and they soon fell into complete disuse.

Lawes and Gilbert *v.* Liebig.—Messrs Lawes and Gilbert were the first experimenters who proved that the "mineral theory" of Liebig did not agree either with actual practice, or experimental results. They grew wheat with Liebig's "wheat manure," with a variety of other mineral compounds, with ammonia sulphate alone, with farmyard manure, and without any fertilisers. Liebig's manure (448 lb.) gave 20⅓ bushels

of dressed corn, and 1676 lb. of straw; whilst "sulphate of ammonia" (224 lb.) alone produced 27⅓ bushels of dressed corn, and 2244 lb. of straw. The addition of 224 lb. of sulphate of ammonia to Liebig's manure increased the yield of dressed corn from 20⅓ bushels to 29¼ bushels, and the produce of straw from 1676 lb. to 2571 lb. Farmyard manure (14 tons) gave of dressed corn 27 bushels, and of straw 2454 lb.; whilst a portion of the land unmanured produced 18 bushels of dressed corn, and 1513 lb. of straw. These experiments show that an increase in the produce of wheat was produced by Liebig's mineral manure, but that it was very small as compared with the augmented yield caused by the application of ammonia salts.

This investigation (in 1845-46) led to a celebrated discussion between Baron Liebig and Messrs Lawes and Gilbert, which continued during many years, and which, in the opinion of the vast majority of scientific agriculturists, ended adversely to the "mineral theory" of the great German chemist. The long-continued experiments of Messrs Lawes and Gilbert, if they prove anything at all, certainly show that nitrogen is that constituent of soils which first fails when cropping is continued without the application of manures. They have up to this date (1881) grown thirty crops of barley in succession in the same field, and the results of this prolonged experiment may be briefly stated as follows:—

1. Without manure of any kind the average yield during twenty-eight years was annually about 17⅞ bushels of dressed corn, and 10⅜ cwt. straw.

2. With ammonia salts alone the average annual

produce amounted to 30¼ bushels of dressed corn, and 17½ cwt. of straw.

3. With nitrate of soda (a nitrogenous manure) the produce was, of dressed corn, 34 bush.—straw, 20 cwt.

4. Farmyard manure (average of 20 years) produced about 44⅛ bushels of dressed corn, and 25⅝ cwt. of straw.

5. Mineral manures gave 24¼ bushels of dressed corn, and 12⅝ cwt. of straw.

6. Mixed nitrogenous and mineral manures gave 44¼ bushels of dressed corn, and 27 cwt. of straw.

These results show that nitrogenous manures give a larger return of produce than mineral manures, and that mixed mineral and nitrogenous manures (including farmyard manure) produce much larger crops of grain and straw than ammoniacal salts, nitrate of soda, or mineral compounds develop when separately applied to barley.

Experiments with wheat, manured with different fertilisers, gave results closely resembling those obtained in the case of barley; but with the natural grasses the difference was not so great between the effects of mineral, as compared with nitrogenous, manures. Thus the annual application of 200 lb. of mixed ammonia salts (equal parts of sal-ammoniac and sulphate of ammonia) to meadow-land, produced, on an average of twelve years, 33⅞ cwt. of hay; another plot, manured yearly for twenty years with 400 lb. of ammonia salts, gave annually only 26½ cwt. of hay: on the other hand, 3½ cwt. of superphosphate gave per acre, for twenty years, an average crop of 22½ cwt.; and mixed mineral manures yielded, during seven years, 31¼ cwt. of hay in one plot; and

during fourteen years, 27½ cwt. in another. The two unmanured plots yielded average crops (during ten years) of 23¾ cwt.; during twenty years, 22½ cwt.; and during five years 1876-80, 16⅞ cwt. Nitrate of soda in one plot, when applied continuously for twenty years, and in the proportion of 550 lb., gave 57 cwt. per acre; in another plot, and during twenty years, an annual application of 375 lb. of nitrate of soda produced, on the average, 33⅞ cwt. of hay. Mixed mineral and nitrogenous manures used continuously during twenty years, developed annually an average crop of 57⅝ cwt. It should be noted that the unmanured plot which produced 32⅞ cwt. of hay on an average of twelve years, had previously received yearly for eight years 14 tons of farmyard manure, during which time its annual crop on the average weighed 42½ cwt.

It may be necessary to explain that the discussion between Liebig and Lawes and Gilbert was not with respect to the nature of the food of plants, but in relation to certain points in practical agriculture. Lawes and Gilbert, though they maintain that *crops* require nitrogenous as well as mineral manures, do not contend that the food of *plants* is not wholly mineral. Liebig, indeed, in his later works, endeavours to prove that he always had included ammonia and its salts amongst his mineral manures; but the study of his earlier writings must convince any impartial person that his original proposition amounted to this, —supply plants with their ash ingredients, and they take care of themselves, so far as their nitrogenous food is concerned.

CHAPTER XXVII.

HOW SOILS LOSE AND GAIN DURING CROPPING.

Exports from the Farm.—A large—usually the larger—proportion of the nitrogen and the mineral matters extracted from the soil by crops is not taken away permanently, but is returned to the earth in the form of stubble, straw, the stems and foliage of certain plants (such as, for example, turnips), and in the *excreta* of the farm animals that have consumed on the spot a portion of the crops. The quantity of mineral matter taken away altogether in animal and vegetable products from the soils of a farm varies, but within moderate limits, according to the system of agriculture adopted on the farm. It sometimes happens that farmers, when their leases are expiring, and are not to be renewed, adopt the plan of taking as much out of the land as they possibly can without giving it anything in return. Under such conditions a large quantity of nitrogen and mineral matters is extracted from the soil; but such a system of cropping cannot be long continued, and is, except perhaps for a year or two, thoroughly unsound. Mr Lawes has shown that in a short time land cropped, but unmanured, refuses to produce paying crops, but is by no means permanently injured. A small proportion of the food of plants contained in the soil is in a highly effective condition, and ready for assimilation. A few corn crops grown in succession take up a large proportion of this immediately available nourish-

ment, and then the land goes *out of condition.* But being out of condition is very different from being reduced to barrenness. In the former case, tillage soon sets free a fresh portion of phosphates and potash, &c., from the rocky portion of the soil; and this operation, together with the application of manure, soon restores the soil to its former state of fertility.

The reason why it is practically impossible to exhaust a soil is simply because, in a very short time, the crops would become so poor as not to repay the cost of labour and the other expenses in connection with their cultivation. Messrs Lawes and Gilbert have shown the results of growing turnips three years in succession in the same field, and without manure. In the first year the yield of roots was 9388 lb.; in the second year, 4956 lb.; and in the third year, 1536 lb. It would be a vain attempt to render land barren by growing root crops therein. In the same field that Lawes and Gilbert could not grow turnips without manure, they raised three crops in succession by applying yearly farmyard manure in the ratio of 12 tons per acre. The first year's crop amounted to 21,233 lb.; the second year's crop increased to 24,108 lb.; whilst in the third year a crop of 38,170 lb. of turnip roots was obtained. In these experiments the beneficial influence of the farmyard manure is clearly evident two years after its first application.

The amount of nitrogen and ash constituents removed from a farm is less if the products sent to market consist of meat, butter, cheese, and milk, than if they are composed wholly of vegetable products such as corn or potatoes. The proportions of

nitrogen and ash constituents removed annually from an acre of land depend upon the system of farming adopted and the nature of the products exported from the farm. If an oat crop minus the straw be sold, it will take away about 60 lb. of mineral matter, including about 12 lb. of phosphoric acid, 9 lb. of potash, and 60 lb. of nitrogen. If the straw were removed from the farm, it would carry off per each acre about 145 lb. of mineral matter, including about 40 lb. of potash, 20 lb. of phosphoric acid, and 15 lb. of nitrogen. A crop of 8 tons of potato-tubers extracts from an acre from 160 to 180 lb. of mineral matter, including from 33 to 36 lb. of phosphoric acid, 80 to 90 lb. of potash, from a trace to 3 lb. of soda, from 4 to 6 lb. of lime, from 7 to 9 lb. of magnesia, from 10 to 13 lb. of sulphuric acid, and about 45 lb. of nitrogen. The potato crop is one of the most exhaustive to the farm, especially in potash.

The following table, based upon Lawes and Gilbert's experience, shows the quantities of the more important matters, removed from the soil by animal products:

COMPOSITION OF THE ANIMAL EXPORTS FROM A FARM.

	Nitrogen.	Phosphoric acid.	Potash.	Lime.	Magnesia.
	lb.	lb.	lb.	lb.	lb.
Fat ox, per 1000 lb. fasted live weight,	23.18	16.52	1.84	19.20	0.63
Fat sheep, per 1000 lb. fasted live weight. . .	19.60	11.29	1.59	12.80	0.50
Fat pig, per 1000 lb. fasted live weight,	17.57	6.92	1.48	6.67	0.35
Milk, 1000 lb., .	5.25	2.03	1.80	1.56	0.16
Wool, unwashed, 1000 lb., . .	73.00	1.00	40.00	1.00	0.70

By "fasted" is meant that the digestive organs of the animals had been almost completely emptied of their contents before they were killed and analysed. These figures will enable the "meat manufacturer" to estimate, with a close approximation to the truth, the amount of nitrogen and mineral matters which in the shape of beef, mutton, pork, milk, and wool is annually extracted from the soils of his farm.

The Soil loses by Drainage.—In addition to the losses which the soil sustains by cropping, it loses no inconsiderable amount of valuable matters in the drainage-waters which flow through it. The amount of ammonia and phosphoric acid lost in this way is not serious — neither is there a sensible waste of potash; but a large quantity of nitrogen is carried off in the form of nitric acid. The results of experiments conducted at Rothamstead show that every inch of rain which passes so low down into the soil as to be beyond the reach of the roots of plants, entails a loss of nitrogen to the extent of 2¼ lb. per acre, if in every gallon of the drainage-water there are seven-tenths of a grain of nitrogen. Voelcker found (Journal of Royal Agricultural Society, vol. x., 1874) that the drainage from a plot of ground—which ground had received a short time previously a heavy dressing of nitrate of soda—contained 5.8 grains of nitrogen (in the form of nitrate of soda) per 100,000 parts. This was equal to a loss of 13 lb. of nitrogen per acre for every inch of rain that passed through the soil.

In the drainage from plots long unmanured with nitrogenous substances, 0.43 of nitrogen per 100,000 parts was found. As nitrogen is taken out of soils

by crops to a greater extent than phosphoric acid or potash—as the loss in nitrogen by drainage is considerable—and finally, as the amount of nitrogen naturally present in the soil is small,—we can readily understand why it is that this is the first element which usually fails when crops are grown without manure.

Voelcker concludes from his experiments that nitrate of soda is best applied to crops when they are growing, or just immediately before the plants appear above ground. Lawes, however, has observed the beneficial effects of nitrate of soda long after its application. The proportion of rain which passes down into the soil beyond the reach of plants has been found by various experimenters to vary from 25 to 42½ per cent. Probably about one-third of the rain-water that falls is lost by drainage, and two-thirds evaporated or used by plants.

Gains to the Soil.—The losses which the soil sustains by part of its produce being exported and by drainage are compensated for, partly or fully, in three ways: 1st, By absorption of combined nitrogen from the atmosphere; 2d, By artificial or natural manures imported into the farm; 3d, By the manure produced on the farm by the use of imported food.

Gain from the Atmosphere.—The soil gains from the atmosphere some of the most valuable of fertilising agents—nitrogen, sulphates, chlorides, water, and carbonic acid. The gain of nitrogen from the air is not equal to the loss of nitrogen in drainage, unless in the case of very poor soils, supplied with but little manure. There are two atmospheric sources of nitrogen—namely, nitric acid and ammonia. They are

both very soluble in water, and if carefully sought for, may always be found in rain. The absolute and relative amounts of ammonia and nitric acid in rain vary in different countries, and in towns and rural districts. Thus, according to Angus Smith, the amounts of ammonia and nitric acid in the rain which descends from the pure atmosphere of Valencia on the coast of the county of Kerry, being taken each as standards, the following relative proportions are present in the rain-waters of other localities :—

	Ammonia.	Nitric acid.
Valencia (Ireland),	1.00	1.00
Inland parts of England,	5.94	2.02
Sea-coast places in Scotland—average,	4.10	1.01
London,	19.17	2.27
Manchester,	35.94	2.79
Glasgow,	50.55	6.72

One million parts of rain-water collected at Valencia contained 0.18 part of ammonia, and 0.37 part of nitric acid. In English inland places, the rain contained 1.07 part of ammonia, and 0.749 part of nitric acid per 1,000,000 parts. In Glasgow rain-water, there are per 1,000,000 parts, 9.1 parts of ammonia, and 2.436 parts of nitric acid. These statements, in 'Air and Rain,' by Angus Smith, do not harmonise with those made by Way, and, very recently, by Frankland, who found the difference between the amounts of nitric acid and ammonia much greater.

About 7 lb. of combined nitrogen fall annually on an acre of land at Rothamstead, and of this quantity about one-ninth exists as nitric acid, and the rest as ammonia. On the Continent the amount of combined nitrogen which descends annually in rain has been

variously estimated at from 1.86 lb. per acre (in Kuschen, Posen) to 20.91 lb. per acre (at Proskau, Silesia); the average is probably about 10 lb.

CHAPTER XXVIII.

THE VALUATION OF UNEXHAUSTED MANURES IN SOILS.

The potash and other substances required by plants exist for the most part in an inert condition in soils—that is, they require to be reduced to a gelatinous or finely pulverulent condition, or to be set free from certain chemical combinations, before they are in a suitable physical condition for absorption by plants. The amount of this immediately available plant-food is at any given time very small as compared with the quantity yet to be set free, or rendered assimilable. The addition of even very small quantities of certain manurial substances to a soil adds largely to the amount of the available plant-food, though it may not sensibly increase the total quantity of fertilising matter in the soil. In estimating the improvements made by an out-going occupier of a farm, it has lately become the practice under certain conditions to place a value upon manures which had been applied to such a farm, but which had not subsequently been wholly removed by crops. It is very difficult to value correctly the unexhausted portion of manures applied from one to say five years previously. Some kinds of

manure are very readily taken up by plants, others pass out of the soil very freely, and a portion may assume that temporarily inert condition in which the great mass of plant-food exists in the soil. Potash and phosphates do not, as we have seen, pass readily out of the soil—neither does ammonia; but nitrate of soda is soon carried out of soils by drainage-water. In determining the value of the residue of manures recently applied, there are two points to be considered; 1st, the original value of the manure—2d, the tendency which it has to pass out of the soil. Mr J. B. Lawes has devoted considerable attention to the elucidation of this difficult matter (Journal of the Royal Agricultural Society, vol. xi. ss. part 1), and to him we are indebted for many valuable data. When an animal consumes say a cwt. of molasses, the manure which is producible from it is worth next to nothing; but if the animal eats a cwt. of linseed-cake, then the disorganised constituents of the cake, which will pass out of its body, will possess considerable manurial value. Mr Lawes has constructed a table which shows the value of the manure produced by the consumption of all the more commonly used feeding-stuffs.

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ESTIMATED VALUE of the MANURE obtained by the CONSUMPTION of different ARTICLES of FOOD, each supposed to be good quality of its kind.

DESCRIPTION OF FOOD.	Money-value of the manure from one ton of each food.		
	£	s.	d.
Cotton seed-cake, decorticated	6	10	0
Rape-cake	4	18	6
Linseed-cake	4	12	6
Cotton-seed-cake, not decorticated	3	18	6
Lentils	3	17	0
Beans	3	14	0
Tares	3	13	6
Linseed	3	13	0
Peas	3	2	6
Indian meal	1	11	0
Locust-beans	1	2	6
Malt-dust	4	5	6
Bran	2	18	0
Coarse pollard	2	18	0
Fine pollard	2	17	0
Oats	1	15	0
Wheat	1	13	0
Malt	1	11	6
Barley	1	10	0
Clover-hay	2	5	6
Meadow-hay	1	10	6
Bean-straw	1	0	6
Pea-straw	0	18	9
Oat-straw	0	13	6
Wheat-straw	0	12	6
Barley-straw	0	10	9
Potatoes	0	7	0
Parsnips	0	5	6
Mangel-wurzel	0	5	3
Swedish turnips	0	4	3
Common turnips	0	4	0
Carrots	0	4	0

It will be observed that the value placed upon the

manure produced from certain foods almost equals the price of the original articles themselves. Thus, decorticated cotton-seed-cake may be bought at £8, 10s. per ton, whilst locust-beans usually realise £6 per ton; yet the manure produced from a ton of cotton seed-cake is about £6, 10s., whilst that obtained from the consumption of a ton of locust-beans is worth only £1, 2s. In valuing, therefore, the unexhausted manure in a farm, it will be necessary to take into account, not the sum of money which has been expended in the purchase of food, but the quantity and kind of the purchased feeding-stuffs.

In valuing the manure produced from a food, it is assumed that the whole of the former is deposited without much waste in the soil. Dr Voelcker, in the twelfth volume ss. (1876) of the Journal of the Royal Agricultural Society, expresses his opinion that Mr Lawes's values of the manures produced from foods are excessive, and suggests that they should be reduced by from 20 to 40 per cent according to the conditions under which the manures were produced. Mr Lawes, however, in his evidence before a special meeting of the chemical committee of the Royal Agricultural Society of England, held on the 3d February 1876, has shown that he has made due allowance for unavoidable waste of manure in considering the value to be placed upon unexhausted manures.

If purchased food be consumed together with a root crop by the animals of the outgoing tenant, and if he has not taken away the crop so manured, then he is, according to Mr Lawes, entitled to 17s. for every 20s. of the original manure-value of the food, or 16s. if the food had been consumed in yards and not in

the fields. If the tenant has taken out a corn crop, sold the grain, and left the straw on the farm, he is entitled to 7s. per 20s. of the original manure-value of the purchased food. If two crops of corn (minus straw) have been removed off the farm, the outgoing tenant's interest in the unexhausted manure is reduced to 5 per cent of the manure-value of the food consumed. If grass or hay be grown and consumed on the farm instead of the second corn crop, 2s. per 20s. of the manure-value of the food should be allowed.

If purchased food be eaten on grass land, and no hay has been removed, the outgoing tenant is entitled to 18s. for every pound's worth of the estimated value of the manure from food. If one crop of hay be consumed on the farm, 11s. will represent the 20s. worth of original manure, and the removal of two crops of hay will reduce the value of the residual manure to 2s. per 20s. of original manure-value of the consumed food. If food which yields 20s. worth of manure be consumed on a permanent pasture, then after one year the value of the manure produced from it will be 18s.; after two years, 12s.; and after three years, 4s.

With respect to the valuation of unexhausted residues of manures applied previous to the development of a crop or crops, nothing should be allowed for the farmyard manure which had been used except for that portion of it which had been produced by the consumption of imported food. Three-fourths of the value of nitrate of soda should be allowed when that manure had been used for roots, and the roots consumed on the land. If the manure produced by consuming the roots be applied to a corn crop, and

the grain of the latter be sold, the value of the residual nitrate of soda may be set down at one-fifth of the cost of the original quantity used. A second corn crop reduces the value of the residual nitrate to 1s. Nitrate of soda applied to a corn crop (the straw being left on the farm) leaves a residue worth 6s. per 20s. expended on the original manure. A second corn crop leaves no nitrate in the soil.

Sulphate of ammonia does not pass away so readily in drainage-water as nitrate of soda ; but still it may be considered to leave the same residues as nitrate of soda under identical conditions.

When superphosphate is applied to roots, and no crop has been taken off the manure produced by their consumption, the value of the residue is equal to 45 per cent of that of the original manure, or 40 per cent if the roots have been consumed in yards. If corn has been grown after the roots, and the grain sold, the manure residue will not be worth more than one-twentieth of the cost of the original manure. 20s. worth of superphosphate on permanent pastures is worth 12s. after one year, 4s. after two years, and nothing after three years.

One pound's worth of guano applied to land under grass is worth 16s. after one year, 10s. after two years, and 2s. after three years. If the grass be removed as hay, only 2s. should be allowed for the manure residue. When guano is applied to a corn crop, and the grain alone sold off the farm, the guano left in the soil is worth about 6s. for every 20s. paid for the original quantity. A second crop of corn leaves no guano worth valuing. If guano be used with roots, and the latter have been consumed upon the

ESTIMATED MONEY-VALUE of the UNEXHAUSTED RESIDUE of MANURES remaining after the Growth of different Crops, expressed in Shillings for every Twenty Shillings original *Manure-Value* of the Purchased Feeding-Stuff or Manure employed.

AFTER		Purchased or saleable food.	Farmyard or town-stable manure.	Rape-cake, or other cake used as manure.	Bones.	Nitrate of soda.	Sulphate of ammonia.	Guano, in natural state or manufactured.	Compound artificial or refuse manures.	Superphosphate, made from mineral phosphates.
		Shillings allowable for every 20 shillings original *manure-value*.								
	Purchased (or saleable) feeding-stuff consumed with roots, or manure applied for roots.									
1st year	Food consumed with roots on land	17	...	...	...	...	...	...	...	..
1st year	Food consumed with roots in yards	16	...	...	...	...	...	...	...	...
1st year	Manure applied to roots consumed on land	...	17	16	17	15	15	15	12	9
1st year	Manure applied to roots consumed in yards	...	16	15	16	14	14	14	10	8
2d year	Corn crop; grain sold, straw left .	7	9	7	8	4	4	4	2	2
3d year	Corn crop; grain sold, straw left .	1	3	1	2	1	2	1	...	...
3d year	Grass or hay consumed . . .	2	5	3	4	2	1	2	...	...
4th year	Grass or hay consumed . . .	...	2	...	1	...	...	...	...	...
3d year	Hay sold	...	2	...	1	...	...	...	...	...

	Manure applied for a corn-crop.									
1st year	Corn crop ; grain sold, straw left .	...	12	7	...	6	6	6	6	5
2d year	Corn crop ; grain sold, straw left .	...	6	1	...	...	...	...	...	...
2d year	Grass or hay consumed . . .	...	8	3	...	1	1	1	1	...
3d year	Grass or hay consumed . . .	...	4	1	...	...	...	...	...	...
2d year	Hay sold	...	4	..	...	...	...	...	...	...
	Feeding-stuff consumed on, or manure applied to, grass-land—grazed.									
1st year	Grazed	18	18	...	18	16	16	16	14	12
2d year	Grazed	12	14	...	13	10	10	10	6	4
3d year	Grazed	4	8	...	6	2	2	2	...	...
4th year	Grazed	...	2	...	1	...	...	...	...	...
	Feeding-stuff consumed on, or manure applied to, grass-land—hay consumed.									
	No crop	18	...	...	...	...	...	...	...	...
1st year	Hay consumed	11	16	...	16	14	14	14	13	10
2d year	Hay consumed	2	12	...	10	8	8	8	4	2
3d year	Hay consumed	...	6	...	3	1	1	1	...	...
4th year	Hay consumed	...	...	...	...	...	...	...	...	...
	Feeding-stuff consumed on, or manure applied to, grass-land—hay sold.									
	No crop	18	...	...	...	...	...	...	...	...
1st year	Hay sold	2	10	...	10	2	2	2	2	...
2d year	Hay sold	...	4	...	4	...	...	...	...	...
3d year	Hay sold	...	...	...	...	...	...	...	...	...

farm, then the guano residue is worth three-fourths the value of the original quantity. If the roots have been consumed, and the manure produced thereby has been applied to a corn crop of which the grain has been sold, then the guano residue is worth not more than one-fifth of the value of the original quantity. 20s. worth of bones applied to grass-land, becomes 18s. worth after one year, 13s. after the second year, 6s. after the third year, and 1s. after the fourth year. If the grass be made into hay and consumed on the farm, the value of the bone residue will be 16s. after the first year, 10s. after the second year, and 3s. after the third year. If the hay be sold, the bone residue will be worth 10s. after the first year, 4s. after the second, and nothing subsequently.

The valuation of unexhausted manures, according to the methods which we have described, though not absolutely trustworthy, may occasionally be found serviceable in adjudications between landlord and tenant, or between the outgoing and the incoming tenant. In applying it, the chief difficulty will be found in those cases in which one or two crops had been taken out since the application of the manure. In the case of manures applied subsequent to the last crop being removed, the data supplied by Mr Lawes will be found very useful, and in the main perfectly accurate. They will at least prevent the reception of excessive claims for unexhausted manures produced by the consumption of molasses, locust-beans, and similar articles.

In the tables on pages 294 and 295, Mr Lawes's estimates of the value of unexhausted manures are fully stated.

CHAPTER XXIX.

THE EFFECTS PRODUCED BY MANURES ON THE QUALITY AND QUANTITY OF CROPS.

The analyses of the ashes of plants show considerable differences in their composition. Some are rich in potash; others contain a large proportion of magnesia; and so on. Now it is evident that in manuring the land for particular crops, due regard should be paid to the requirements of the plants; for example, as potatoes are rich in potash, a special manure for potatoes should contain potassium salts. As clover abounds in sulphuric acid, gypsum (calcic sulphate), or potassic sulphate, may reasonably be regarded as suitable manures for that crop.

The influence of manures upon plants has been proved by many experiments, and by the experience of both the agriculturist and the horticulturist. Thus the gardener is said to improve his roses by adding manganese compounds to the soil, and to redden his hyacinths by watering them with solution of sodic carbonate. Wolff states that potassic carbonate promotes the growth of the stem and leaves of the vine. The striking effect which lime produces in causing abundance of white clover to spring, as if by magic, out of the soil, where not a blade apparently existed previously, is known to every farmer.

Every one knows that some soils naturally produce much larger returns of wheat, oats, and barley than others do, and that the same soil will produce

more or less according to the mode in which the land has been prepared—by manure or otherwise—for the reception of the seed. The following table shows the effect produced upon the quantity of the crop by *equal quantities* of different manures applied to the *same soil*, sown with an equal quantity of the same seed :—

	Return in bushels from each bushel of seed.			
Manure applied.	Wheat.	Barley.	Oats.	Rye.
Blood, . . .	14	16	12½	14
Nightsoil, . .	—	13	14½	13½
Sheep's dung, . .	12	16	14	13
Horses' dung, . .	10	13	14	11
Pigeons' dung, .	—	10	12	9
Cows' dung, . .	7	11	16	9
Vegetable manure, .	3	7	13	6
Without manure, .	—	4	5	4

It is probable that on different soils the returns obtained by the use of these several manures may not be uniformly in the same order, yet it will always be found that nitrogenous guano, blood, nightsoil, and sheep, horse, and pigeons' dung, are among the most enriching manures that can be employed.

It is a practical fact, bearing upon this point, that in some parts of Bedfordshire, high farming causes barley to run to straw, to the injury of the corn; while, on the contrary, the wheat increases in yield with higher cultivation.*

Two facts will particularly strike the practical man on looking at the above table.

1. That, exclusive of blood, sheep's dung, in these experiments, gave the greatest increase in the barley crop. The favourite Norfolk system of eating off tur-

* Caird's English Agriculture, 451.

nips with sheep previous to barley, besides other benefits which are known to attend the practice, may possibly owe part of its acknowledged utility to this powerful action of sheep's dung upon the barley crop. Still, too much reliance is not to be placed on such special results till the experiments have been carefully repeated.

2. The action of cows' dung upon oats is equally striking; and the large return of this crop (thirteen-fold) obtained by the use of vegetable manure alone, may perhaps explain why, in poorly-farmed districts, oats should be a favourite and comparatively profitable crop, and why they may be cultivated with a certain degree of success on land to which rich manure is rarely added.

It is possible that results different from those recorded in the above table may be obtained by a careful repetition of the same experiments on soils of different kinds, and in different circumstances. It is very desirable, therefore, that such experiments should be undertaken, accurately conducted, and carefully recorded.

Manures do not always produce the same effects in different districts. Thus bones, which produce such wonderful effects in Great Britain, especially upon turnips, and upon some old grass-lands as those of Cheshire, are much less conspicuously effective in some parts of Germany, and even of our own island —on some of the soils of the greensand, for example; while gypsum so much and so generally prized by the German and American farmer, is more rarely found to answer the expectations of the English agriculturist.

The truth is, that if the crop we wish to raise specially requires any one substance which is not present in sufficient quantity in the soil, that substance will there prove a specific for that crop; while, in another soil in which it is already abundantly present, this substance will produce little beneficial effect. Failures, therefore, may every now and then be expected in the use of so-called *specific manures*, the evil of which is not limited to THE IMMEDIATE LOSS experienced by the incautious experimenter. They serve also to dishearten those who, through their much faith, have been disappointed in their expectations, and thus to retard the progress of a truly rational experimental agriculture.

The same remark applies also to artificial *mixed* manures, when held forth as specifics for any or for all crops on every soil. The animal and vegetable manures which occur in nature are all mixtures of a considerable number of different substances, organic and inorganic. We are imitating nature, therefore, and are in reality so far on the right road when we compound our artificial mixtures. The soil may be deficient in two, three, or more substances; and to render it fertile, it may be necessary to add all these; while, if it be defective in one only, we are more likely to administer the right one, if we add a mixture of several at the same time. It is *safer* and *surer*, therefore, to add several saline substances to our soils.

There are only two ways in which we can safely make up mixtures that are likely to be useful—either by actual experiment upon the kind of land we wish to improve, or by an exact imitation of the procedure, and by attention to the requirements, of nature.

The most elaborate and carefully conducted experiments ever undertaken to ascertain the action of manures on crops are those that have been in progress for the last thirty-three years, under the direction of Dr John Bennet Lawes and Dr J. H. Gilbert, on the estate of the former, at Rothamstead, Hertfordshire. In the following tables most of the results of these experiments are epitomised :—

ACREABLE PRODUCE OF BARLEY GROWN YEAR AFTER YEAR ON T SAME LAND WITH AND WITHOUT MANURES.

MANURES, PER ACRE, PER ANNUM.	28 Years, 1852-79.	28 Years, 1852-79.	Twenty-nint season, 188	
	Corn.	Straw.	Corn.	Str
	bush.	cwt.	bush.	cv
Unmanured continuously	17⅞	10⅜	18¾	9
3½ cwt. superphosphate of lime	23	11⅞	28⅝	13
200 lb. (1) sulphate potass, 100 lb. sulphates of soda (2) and magnesia	19¾	10⅝	23¾	10
200 lb. (1) sulphate potass, 100 lb. sulphates of soda (2) and magnesia, 3½ cwt. superphosph.	24¼	12⅝	30⅛	13
100 lb. each of sulph. and chloride of ammonia	30¼	17⅛	33⅞	15
200 lb. ammonia-salts, and 3½ cwt. superphos.	44⅝	25½	55¾	26
200 lb. ammonia-salts, 200 lb. (1) sulph. potass, 100 lb. (2) sulph. soda, 100 lb. sul. magnesia	33	19¼	38⅛	18
200 lb. ammonia-salts, 200 lb. (1) sulphate potass, 100 lb. (2) sulph. soda, 100 lb. sulph. magnesia, 3½ cwt. superphosphate	44¼	27	54¾	29
275 lb. nitrate soda (3)	34	20	38¼	18
275 lb. nitrate soda (3), and 3½ cwt. superphos.	46½	28⅜	57¼	29
275 lb. nitrate soda (3), 200 lb. (1) sulph. potass, 100 lb. (2) sulph. soda, 100 lb. sulph. magnesia	34⅝	21⅞	41¼	21
275 lb. nitrate soda, 200 lb. (1) sulphate potass, 100 lb. (2) sulphate soda, 100 lb. sulphate magnesia, 3½ cwt. superphosphate	46⅝	30	59⅜	32
1000 lb. rape-cake (4)	43	25⅛	50¼	24
1000 lb. rape-cake (4), 3½ cwt. superphosphate	44½	26⅜	56	28
1000 lb. rape-cake (4), 200 lb. (1) sulph. potass, 100 lb. (2) sulph. soda, 100 lb. sulph. magnesia	41¼	25⅛	51¾	27
1000 lb. rape-cake (4), 200 lb. (1) sulph. potass, 100 lb. (2) sulphate soda, 100 lb. sulphate magnesia, 3½ cwt. superphosphate	45¼	27½	55	32
200 lb. (1) sulph. of potass (5) and of ammonia-salts, and 3½ cwt. superphosphates	42 (6)	26⅜ (6)	54¾	36
100 lb. sulphates of soda and magnesia, 3½ cwt. superphosphates	19¼ (7)	11⅛ (7)	30⅜	14
Farmyard manure, 14 tons, 20 years, 1852-71	44⅛ (8)	25⅝ (8)	41¾	19

(1) 300 lb. per annum for the first 6 years, 1852-57. (2) 200 lb. per annum for the first 6 y 1852-57. (3) First 6 years, 1852-57, instead of nitrate of soda, 400 lb. ammonia-salts per ann next 10 years, 1858-67, 200 lb. ammonia-salts per annum; 1868 and since, 275 lb. nitrate of per annum. (4) 2000 lb. rape-cake per annum for the first 6 years, and 1000 lb. only each since. (5) By mistake 400 lb. in 1880. (6) Averages of 13, 14, and 27 years. (7) A ages of 8 years, 13 years, and 21 years. (8) Averages of 20 years (with dung), 8 years (um ured), and 28 years.

EXPERIMENTS ON THE GROWTH OF OATS—*continued.*

ECOND 5 YEARS; MINERAL MANURES AS BEFORE, AMMONIA-SALTS AND NITRA OF SODA ONLY HALF AS MUCH AS PREVIOUSLY.

MANURES, PER ACRE, PER ANNUM.	PRODUCE PER ACRE.							
	1874.		1876.		1878.		Average p annum, 4 ye 1874-78.	
	Corn.	Straw.	Corn.	Straw.	Corn.	Straw.	Corn.	Stra
	bush.	cwt.	bush.	cwt.	bush.	cwt.	bush.	cw
Jnmanured	12	7	8⅛	2⅝	22¼	8⅜	13¾	6
00 lb. sulphate potass, 100 lb. sulphate soda, 100 lb. sulph. mag., and 3½ cwt. superphosphate of lime (1) . .	13⅝	6½	7¾	2⅝	17¾	8¼	13⅛	6
00 lb. ammonia-salts (2) .	37¼	22⅞	17⅝	6	30	12⅜	28⅞	14
00 lb. ammonia-salts, 200 lb. sulph. potass, 100 lb. sulph. soda, 100 lb. sulph. mag., and 3½ cwt. superphos. .	46¾	24⅝	29¼	12½	45⅜	22½	38	20
75 lb. nitrate of soda (3) .	35⅛	16½	12¾	3⅞	34⅛	12½	26⅜	11
75 lb. nitrate of soda, 200 lb. sulph. potass, 100 lb. sulph. soda, 100 lb. sulphate mag., and 3½ cwt. superphos. .	28½	16⅝	19⅝	8	37	17½	28½	14

(1) "Superphosphate of lime"—in all cases, made from 200 lb. bone-ash, 150 lb. sulphuric acid . 1.7 (and water).
(2) "Ammonia-salts"—in each case, equal parts sulphate and muriate of ammonia of commerc
(3) 550 lb. nitrate of soda is reckoned to contain the same amount of nitrogen as 400 lb. "ammo lts."

In the experiments with barley, the best effects are seen where nitrogenous manures have been used. Ammoniacal salts gave a smaller return than nitrate of soda, whilst rape-cake exceeded both. From this we infer that the nitrogen is more effective for cereals when it is in the form of nitric acid than when it exists as ammonia. Purely mineral manures produced but little increase in the yield, the best of them being superphosphate. The addition of mineral manures to nitrogenous manures did not add much to

the effect of the latter unless the former included superphosphate of lime. Farmyard manure or a mixture of nitrate of soda and superphosphate, and a mixture of ammonia-salts or of rape-cake, with superphosphate, produced nearly the same results, the difference, however, being very slightly in favour of the farmyard manure. Ammonia-salts, or nitrate of soda, with mineral matters, have produced, for twenty-four years, heavier crops of barley and of wheat than the average amount of these crops throughout the United Kingdom. These manures did not include silica or organic matter, and therefore it may be safely assumed that these substances need not be specially applied to wheat or barley, though silicates of potassium and sodium are sometimes employed as manures for the cereals.

One of the most remarkable results of these experiments is, that it is possible to grow white crops without manure for many years. In 1880, the thirty-seventh of the crops of wheat which had been grown in uninterrupted succession on the same field and without manure, produced 11½ bushels of dressed grain (each bushel weighing 56⅞ lb.) and 10¼ cwt. of straw. The general results of that experiment, however, show that the crops of wheat and barley in the unmanured plots are becoming lighter every year; but this diminution in the produce is very trifling, unless when we compare periods of five or ten years. Thus, during the first fourteen years of the growth of barley without manure, the average annual yield of dressed corn was 21¾ bushels, whilst on the following twelve years the yield of dressed corn was annually, on the average, 14 bushels. It is curious to note that the

average weight of a bushel of wheat or barley was greater on all the plots during the second fourteen years than in the first fourteen years: 1880 was a favourable year for barley.

In the trials with oats, the favourable effects of the nitrogenous manures as against the purely mineral manures is remarkable. During the sixth and seventh years the differences between the crops on the unmanured ground and the plot with purely mineral manures are next to nothing. On the other hand, the crops on the plots manured by nitrate of soda and ammonia are three times as large as that produced on the unmanured plot.

Experiments with beans have shown that mineral manures (especially potash compounds) produce excellent effects during the earlier years, and also, but to a more limited extent, in after-years, during good seasons. On the other hand, ammonia-salts produce but little effect, although beans are far richer in nitrogen than cereal plants. Nitrate of soda produces more effect than ammonia-salts in promoting the growth of the bean and of other leguminous crops. It would, however, seem at present impossible to grow beans continuously on the same field without deterioration, even though farmyard manure be abundantly supplied to them.

With respect to clovers, Messrs Lawes and Gilbert have remarked (Journal of Royal Horticultural Society of London, vol. iii. 1872) that when land is not "clover-sick" the crop may be generally benefited by top-dressings containing superphosphate of lime and potash; but that the high price of potash-salts, and the uncertainty of their action upon the clovers,

render their application of doubtful economy. As for land clover-sick, no manure is at present known which is capable of restoring it to a healthy condition in one season; that is, no clover must be grown on it for some years. In a report in 'Biedermanns' Central-Blatt für Agrikultur Chemie,' vol. ix. No. 12, 1881, by Professors J. Kühn, von Liebenberg, and Marck, and Dr Liebscher, turnip sickness is described as a disease caused by multiplication of nematode worms, and not by deficiencies of soil ingredients.

In the case of root crops, phosphoric acid appears to be the most effective manure. Without manure, the produce in two or three years is reduced to a few cwts.; but with abundance of manure, nitrogenous and mineral, large crops can be obtained year after year on the same field.

One of the series of experiments conducted at Rothamstead has shown the remarkable influence which manures have in favouring the development of particular crops, and thereby, in an indirect way, of injuring other crops. These experiments were conducted on 7 acres of permanent meadow-land, which had probably been under grass for centuries, and in which no seed was known to have been sown for 40 years at least. The experiments were commenced in 1856, at which period the herbage appeared to be uniform over all the plots. Excepting as explained in the table which follows, and the foot-notes attached thereto, the same description of manure has been applied, year after year, to the same plot.

The following table, condensed from a more elaborate one, shows the nature of the manures applied to, and the produce of, each plot during 25 years:—

Experiment with different Manures on Permanent Meadow-Land.

The land has probably been laid down with grass for some centuries. No fresh seed has been artificially sown within the last forty years.

Manures, per acre, per annum.	Produce of Hay per Acre (First Crop). Average per Annum. 20 years, 1856-75.	Average per Annum. 5 years, 1876-80.	Twenty-fifth season, 1880.
	cwt.	cwt.	cwt.
1856-63, 8 years, 14 tons farmyard manure, and 200 lb. ammonia-salts (1); average produce 49½ cwt. 1864 and since, 200 lb. ammonia-salts alone; average produce (12 years, 1864-75) 38⅞ cwt.	43	32¼	15
1856-63, 8 years, 14 tons farmyard manure; average produce 42⅞ cwt. 1864 and since, unmanured; average produce (12 years, 1864-75) 32⅞ cwt.	36⅞	23½	11
Unmanured continuously	21¼	16⅞	7½
3½ cwt. superphosphate of lime (2)	22¼ (9)	20⅜	9
3½ cwt. superphosphate of lime, and 400 lb. ammonia-salts	32¼ (9)	33¾	15¼
400 lb. ammonia-salts	26¼	19½	8¼
1856-68, 13 years, 400 lb. ammonia-salts; average produce 30½ cwt. (3) 1869-78, 300 lb., 1879 and since, 500 lb. sulphate potass, 100 lb. sulphates soda and magnesia, 3½ cwt. superphosphate; average produce (7 years, 1869-75) 31¼ cwt. (3)	30¾	34¾	23½
1856-78, 300 lb., 1879 and since, 500 lb. sulphate potass, 100 lb. (4) each sulphates soda and magnesia, 3½ cwt. superphosphate	35¼	35⅝	22½
1856-61, 6 years, 300 lb. sulphate potass, 200 lb. sulphate soda, 100 lb. sulphate magnesia, and 3½ cwt. superphosphate; average produce 36 cwt. (3) 1862 and since, 250 lb. (5) sulphate soda, 100 lb. sulphate magnesia, and 3½ cwt. superphosphate; average produce (14 years, 1862-75) 27½ cwt. (3)	30⅛	25¼	16½

1836-51, 6 years, 300 lb. sulphate potass, 200 lb. sulphate soda, 100 lb. sulphate mag., 3½ cwt. superphosph., 400 lb. ammonia-salts; average produce 55½ cwt. 1862 and since, 250 lb. (5) sulphate soda, 100 lb. sulphate magnesia, 3½ cwt. superphosph., 400 lb. ammonia-salts; average produce (14 years, 1862-75) 42¼ cwt. (9)	46⅛	40¼	25¾
1856-78, 300 lb., 1879 and since, 500 lb. sulphate potass, 100 lb. (4) sulphate soda, 100 lb. sulphate magnesia, 3½ cwt. superphosphates, 800 lb. (6) ammonia-salts	57⅝	53	30
1856-78, 300 lb., 1879 and since, 500 lb. sulphate potass, 100 lb. (4) sulphate soda, 100 lb. sulphate magnesia, 3½ cwt. superphosphates, 800 lb. (6) ammonia-salts, and 400 lb. silicated soda (7)	62½	62½	44¾
Unmanured continuously	24	17⅝	9⅝
1856-78, 300 lb., 1879 and since, 500 lb. sulphate potass, 100 lb. (4) sulphate soda and magnesia, 3½ cwt. superphosph., 400 lb. ammonia-salts, 2000 lb. cut wheat-straw	57½	59	51¼
550 lb. nitrate of soda (8), 1858-78, 300 lb., 1879 and since, 500 lb. sulphate potass, 100 lb. each (4) sulphate soda and magnesia, 3½ cwt. superphosphates . .	57 (10)	54⅝	51⅜
1858-75, 18 years, 550 lb. nitrate soda; 1876-78, 300 lb., 1879 and since, 500 lb., 100 lb. sulphates potass, soda, and magnesia, and 3½ cwt. superphosphates	35⅜ (10)	28½	19
275 lb. nitrate soda, 1858-78, 300 lb., 1879 and since, 500 lb., sulphate potass, 100 lb. each (4) sulphate soda and magnesia, 3½ cwt. superphosphates . . .	46½ (10)	44¾	37⅛
275 lb. nitrate of soda	33⅞ (10)	29⅛	21½
Mixture supplying the quantity of potass, soda, lime, magnesia, phosphoric acid, silica, and nitrogen, contained in 1 ton of hay (commencing 1865) . .	32⅛ (11)	34⅝	20
275 lb. nitrate of soda, 290 lb. sulphate of potass, and 3½ cwt. superphosphate (commencing 1872)	38⅝ (12)	39⅝	31½

(1) "Ammonia-salts"—in all cases equal parts sulphate and muriate of ammonia of commerce.

(2) The "superphosphate of lime" is, in all cases, made from 200 lb. bone-ash, 150 lb. sulphuric acid sp. gr. 1.7 (and water).

(3) Plots 6, 8, and 10 had, besides the manures specified, 2000 lb. sawdust per acre per annum for the first 7 years, 1856-62, but without effect.

(4) 200 lb. 1856-63 inclusive.

(5) 500 lb. in 1862 and 1863.

(6) Only 400 lb. in 1859-60-61.

(7) The application of silicates did not commence until 1862; 9 years (1862-70), 200 lb. silicate lime, and 200 lb. silicate soda 1871 and since, 400 lb. silicate soda.

(8) 550 lb. nitrate of soda is reckoned to contain the same amount of nitrogen as 400 lb. of "ammonia-salts."

(9) The manures specified were first applied in 1859 (previously, 1856-7-8, sawdust only).

(10) Averages of 8 years, 10 years, and 18 years, as these experiments did not commence until 1858.

(11) Averages of (1 year), 10 years, and 11 years, as the experiment only commenced in 1865.

(12) Averages of 4 years only, 1872-75.

During twenty years the average crop of grass on an unmanured plot amounted to 21¼ cwt., and the quantity of nitrogen annually removed from the soil was 36 lb. Ammonia-salts added 5 cwt. to the amount of the crop; and with nitrate of soda, the increase, as compared with the produce of the unmanured plot, was 12½ cwt. per acre. The produce from superphosphate was less than that obtained from one unmanured plot, and but little in excess of the yield from a second unmanured plot. Ammonia-salts and superphosphate combined produced only moderate crops; whilst the highest yield (an average of 62½ cwt. per acre) was obtained by the application annually of a mixture of potassic, sodic, and magnesic sulphates, sodic silicate, ammonia-salts, and superphosphate of lime. Farmyard manure produced fair but not heavy crops. This manure is slow in its action, but it is a perfect fertiliser, and restores everything to the soil which crops abstract from it. On meadow-land the application of farmyard manure tends to promote the development of the superior kinds of herbage, and therefore, though they may not be so abundant as that produced by the use of other manures, their quality is extremely good. The beneficial influence of potash-salts as a manure for grasses has been repeatedly demonstrated, and is strikingly apparent in the Rothamstead experiments.

The most remarkable result of the experiment of applying different manures to grass-land, originally of the same nature, is the botanical changes which have been produced on the herbage. The following is a list of the plants found on all the experimental plots:—

LIST OF PLANTS on Permanent Meadow-land at Rothamstead.

1. *Ranunculaceæ.*—(1) Ranunculus acris, (2) R. repens, (3) R. bulbosus, (4) R. auricomus, (5) R. Ficaria.

2. *Cruciferæ.*—Cardamine pratensis.

3. *Caryophylleæ.*—(1) Stellaris graminea, (2) Cerastium triviale.

4. *Hypericineæ.*—Hypericum perforatum.

5. *Leguminosæ.*—(1) Ononis arvensis, (2) Trifolium repens, (3) T. pratense, (4) T. procumbens, (5) Lotus corniculatus, (6) Lathyrus pratensis, (7) Vicia Cracca, (8) V. sepium.

6. *Rosaceæ.*—(1) Potentilla reptans, (2) P. Fragariastrum, (3) Alchemilla vulgaris, (4) Agrimonia Eupatorium, (5) Poterium Sanguisorba, (6) Spiræa Ulmaria.

7. *Umbelliferæ.*—(1) Conopodium denudatum, (2) Pimpinella Saxifraga, (3) Heracleum Sphondylium, (4) Anthriscus sylvestris.

8. *Rubiaceæ.*—(1) Gallium verum, (2) G. Aparine.

9. *Dipsaceæ.*—Scabiosa arvensis.

10. *Compositæ.*—(1) Centaurea nigra, (2) Carduus arvensis, (3) Bellis perennis, (4) Achillea Millefolium, (5) Chrysanthemum Leucanthemum, (6) Senecio erucæfolius, (7) Hypochæris radicata, (8) Tragopogon pratensis, (9) Leontodon hispidus, (10) L. autumnalis, (11) Taraxacum officinale, (12) Hieracium Pilosella, (13) Sonchus oleraceus.

11. *Plantagineæ.*—(1) Plantago lanceolata, (2) P. media.

12. *Scrophularinæ.*—(1) Veronica Chamædrys, (2) V. serpyllifolia.

13. *Labiatæ.*—(1) Thymus Serpyllum, (2) Prunella vulgaris, (3) Ajuga reptans.

14. *Primulaceæ.*—Primula veris.

15. *Polygonaceæ.*—(1) Rumex Acetosa, (2) R. obtusifolius, (3) R. crispus.

16. *Orchidaceæ.*—Orchis Morio.

17. *Liliaceæ.*—(1) Scilla nutans, (2) Fritillaria Meleagris, (3) Ornithogalum umbellatum.

18. *Juncaceæ.*—(1) Luzula campestris, vars. campestris and congesta.

19. *Cyperaceæ.*—Carex præcox.

20. *Gramineæ.*—(1) Anthoxanthum odoratum, (2) Alopecurus pratensis, (3) Phleum pratense, (4) Agrostis vulgaris, (5) Aira cæspitosa, (6) Holcus lanatus, (7) Avena elatior, (8) A. pubescens, (9) A. flavescens, (10) Poa pratensis, (11) P. trivialis, (12) Briza media, (13) Dactylis glomerata, (14) Cynosurus cristatus, (15) Festuca ovina (varieties), (16) F. pratensis, (17) Bromus mollis, (18) Lolium perenne.

21. *Filices.*—Ophioglossum vulgatum.

22. *Musci.*—(1) Hypnum squarrosum, (2) H. rutabulum, (3) H. hians.

23. *Fungi.*—(1) Agaricus arvensis, (2) A. nudus, (3) A. æruginosus, (4) A. geotrupus, (5) A. furfuraceus, (6) Boletus erythropus, (7) Clavaria vermicularis, (8) Hygrophorus coccineus, (9) H. virgineus, (10) H. pratensis, (11) Marasmius oreades.

The complete flora includes 93 species, 67 genera, and 23 orders. Some of the plants—such, for instance, as *Ranunculus auricomus*, *Vicia Cracca* and *sepium*, *Gallium Aparine*, *Sonchus oleraceus*, *Fritillaria Meleagris*, *Ornithogalum umbellatum*, and about twenty other species, constitute an insignificant proportion of the crop.

In the years 1862, 1867, and 1872, botanical analyses showed the following state of things on four of the principal plots :—

PERCENTAGE BOTANICAL COMPOSITION OF MEADOW-HAY VARIOUSLY MANURED.

Manuring.	1862.			1867.			1872.			1877.			Mean of 1862, 1867, 1872, and 1877.		
	Gramineæ.	Leguminosæ.	Other orders.	Gramineæ.	Leguminosæ.	Other orders.	Gramineæ.	Leguminosæ.	Other orders.	Gramineæ.	Leguminosæ.	Other orders.	Gramineæ.	Leguminosæ.	Other orders.
No manure, ...	71.52	7.15	21.33	62.27	8.07	29.66	66.18	9.58	24.24	69.74	8.01	22.25	67.43	8.20	24.37
Mixed cinereals, . . .	64.65	24.70	10.65	59.29	12.69	28.02	48.82	39.77	11.41	74.38	13.71	11.91	61.78	22.72	15.50
Ammonium-salts, . .	86.32	0.12	13.56	71.85	0.34	27.81	84.70	0.46	14.84	94.06	0.19	5.75	84.23	0.28	15.49
Mixed cinereals and 400 lb. ammonium-salts per acre, . .	88.59	0.13	11.28	77.06	0.16	22 78	92.19	0.02	7.79	94.65	0.41	4.94	88.12	0.18	11.70
Mixed *cinereals* and 800 lb. ammonium-salts per acre, . .	89.38	0.01	10.61	94.12	0.01	5.87	98.84	0.01	1.15	97.53	..	2.47	94.97	0.01	5.02

Species belonging to the order gramineæ have, on the average, made up about 68 per cent of the weight of the herbage on the unmanured plot, about 62 per cent of that grown by purely mineral (and non-nitrogenous) manures, and about 95 per cent of the herbage manured with a mixture of nitrogenous and mineral compounds. Leguminous plants have constituted about 8 per cent of the produce of the unmanured plot, about 23 per cent of that of the plots manured with purely mineral substances, and less than 0.01 per cent of the weight of the herbage grown by mixed mineral and nitrogenous manure. Species of other orders have constituted about 24 per cent of the unmanured produce, 15 per cent of that on the plots supplied with mineral manures, and 5 per cent of the crop on the plot manured by mineral salts and (in large quantity) ammonia-salts. On the plot manured with 550 lb. of sodic nitrate, 300 lb. of potassic sulphate, 100 lb. each of sodic and magnesic sulphates, and 3½ cwt. of superphosphate of lime (per acre), *Poa trivialis* and *Bromus mollis* have attained to an enormous degree of development. In 1872 they formed 66.86 per cent of the weight of the total herbage of the plot. In the same year, on a plot manured with 400 lb. of ammonia-salts and 3½ cwt. of superphosphate of lime (per acre), 49.29 per cent of the herbage was made up of *Festuca ovina*, and 20.59 per cent of the weight of the herbage was furnished by the *Agrostis vulgaris*. In 1877, the produce of the same plot contained 55.2 per cent of *Festuca ovina*, and 24.29 per cent of *Agrostis vulgaris*. One plot has been manured with 800 lb. of ammonia-salts, 300 lb. of potassic sulphate, 100 lb. each of sodic and

magnesic sulphates, and $3\frac{1}{2}$ cwt. of superphosphate of lime. This enormous quantity of manure has stimulated the coarse-growing grasses to such an extent that they have become giants of their kind, and they have crushed out, so to speak, about 30 species of more tender nature, some of which on the unmanured plot resist successfully the coarser plants. *Festuca ovina* forms 21.67 per cent of the produce of the unmanured plot, and is almost without a representative on one of the highly manured plots (11, 1). On the other hand, *Dactylus glomerata* contributes 40 per cent to the herbage of plot 11, 1, and hardly 1 per cent to that of the unmanured plot. These interesting facts—a few only of which are here adduced—show how much we have yet to learn in reference to the effect of manures on crops.

CHAPTER XXX.

FARMYARD MANURE AND ANIMAL EXCREMENTS.

Farmyard Manure is a complex fertiliser of variable composition and value. It consists essentially of straw-litter and the *excreta* of oxen and horses, but it also often contains the excrements of the pig and sheep, house-offal, turnip and mangel tops, and various other refuse matters. The excrements of fattening animals being almost altogether retained by their litter, a rich manure is the result. The nature of the litter has also some—but less—influence on the quality of the manure; straw contributing most, and sawdust least, fertilising materials to the compost.

Percentage Composition of Farmyard Manure.

	1. Lawes & Gilbert (calculated.)	2. Anderson.	3. Boussingault.	4. Voelcker.		5. E. Wolff.	6. Cameron.	
				Fresh.	Rotten.		Fresh.	Long exposed to rain.
Water, ...	70.00	72.48	79.30	66.17	75.42	75.00	69.14	73.22
* Organic matter, ...	27.23	13.94	14.03	28.24	16.53	18.09	24.21	21.17
† Ash, ...	2.77	13.58	6.67	5.59	8.05	6.91	6.65	5.61
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
* Containing nitrogen, . . .	0.64	0.38	0.41	0.64	0.71	0.53	0.50	0.12
† Containing potash, and	0.53	0.32	not	0.67	0.49	0.68	not	not
Phosphoric acid, . . .	0.23	0.31	stated.	0.31	0.45	0.32	stated.	stated.

The small amount of ash in the (calculated) composition of the manure by Lawes & Gilbert is accounted for by the fact that in the ordinary manure there is always some earthy matter mixed up. The fresh manure analysed by Voelcker was fourteen days old; it was composed of litter and the *excreta* of horses, cows, and pigs: the rotten manure was six months old. Anderson's analysis refers to the average composition of eight specimens of farmyard manure produced upon Scotch farms, and which appear on the whole to be poor fertilisers. No. 8 analysis is that of farmyard manure exposed for months to rain, by which much of its soluble matters had been washed out.

The following is a complete analysis of farmyard manure fourteen days old, and composed of horse, cow, and pig dung:—

100 parts contain—

Water,		66.17
* Soluble organic matter,		2.48
Soluble inorganic matter (ash):—		
Soluble silica,	.237	
Tricalcic di-phosphate,	.299	
Lime,	.066	
Magnesia,	.011	
Potash,	.573	
Soda,	.051	
Sodic chloride,	.030	
Sulphuric acid,	.055	
Carbonic acid and loss,	.218	
		1.54
† Insoluble organic matter,		25.76

Insoluble inorganic matter (ash) :—

Soluble silica,	.907	
Insoluble silica,	.561	
Oxide of iron, alumina, with phosphates,	.596	
(Containing phosphoric acid,	.178)	
(Equal to bone earth,	.386)	
Lime,	1.120	
Magnesia,	0.143	
Potash,	.099	
Soda,	.019	
Sulphuric acid,	.061	
Carbonic acid and loss,	.484	
		4.05
		100.00
* Containing nitrogen,		.149
† Containing nitrogen,		.409
Whole manure contains free ammonia,		.034
,, ,, ,, in form of salts,		.088

Animal Excreta.—The urine of animals is far more valuable as a manure than their solid excrements, yet greater care is taken to preserve the latter, the former being in great part too often allowed to run into the drains. The following is the approximative composition of the solid and liquid excrements of the animals of the farm.

Cow-dung is the most abundant, and least valuable in composition, of the animal manures. It decomposes slowly, giving out but little heat; hence it is said to be a *cold* manure. This is quite correct, for manures such as horse-dung which decompose rapidly in the soil, warm the latter. Decomposition in such cases is really a slow combustion. The urine of oxen is richer in fertilising matters than their solid excrements; yet we often find that farmers who take

good care of the dung of their oxen permit the urine to be wasted.

Horse-dung is more valuable than cow-dung. It contains less water, is not so coherent, and does not form during its decomposition an unctuous mass such as cow-dung does. Horse-dung decomposes rapidly, and is therefore a *hot* manure. It is a useful addition to cow-dung, as it renders the latter more friable, whereby it can be more equably distributed throughout the soil.

Sheep-dung decomposes more rapidly than cow-dung, and not so quickly as horse-dung. It is richer in solid matters than the former.

Pig-dung.—The pig being almost an omnivorous animal, its excrements vary in composition according to the nature of its food. Its dung is soft and compact, and it decomposes slowly. It is one of the richest kinds of animal manure; but it is alleged that when used alone as a manure, it gives a disagreeable flavour to roots. On the Continent, pig-dung is largely applied to the hemp crop.

Recent analyses of the liquid and solid excrements of the farm animals are wanted, as those made some years ago are discrepant in many of their results. In *Gorup-Besanez's Lehrbuch der Physiologischen Chemie*, the following analyses are given:—

COMPOSITION OF ANIMAL FÆCES.

100 parts of each contain—

	Pig.	Cow.	Sheep.	Horse
Water, ...	77.13	82.45	56.47	77.25
Solid matters, . .	22.87	17,55	43.53	22.75
	100.00	100.00	100.00	100.00

	Pig.	Cow.	Sheep.	Horse.
Ash, ...	8.50	2.67	5.87	3.04
The ash includes, per 100 parts—				
Potash, ...	3.60	2.91	8.32	11.30
Phosphoric acid, . .	5.39	8.47	9.40	10.22

In Stöckhardt's 'Agricultural Chemistry,' the composition and money value (in Germany) of animal excrements are given as follows :—

COMPOSITION OF DUNG OF ANIMALS.

	Cows fed during winter.	Horses fed during winter.	Sheep fed upon nearly 2 lb. hay daily.	Horses fed upon strong food during winter.
Water, . . .	840	760	580	800
* Solid matters, .	160	240	420	200
	1000	1000	1000	1000
* Including—				
Nitrogen, . .	3	5	7.5	6
Potash and soda,	1	3	3	5
Money value, per 1000 lb., . .	3s.	5s.	7s. 8d.	5s. 8d.

According to Stöckhardt, cow's urine contains 8 per cent of solid matters (including 0.8 per cent nitrogen, and 1.4 per cent potash and soda); horse's urine, 11 per cent of solids (including 1.2 per cent nitrogen, and 2 per cent potash and soda); sheep's urine, 13 per cent of solids (including 1.4 per cent nitrogen, 2 per cent potash and soda, and 0.05 per cent phosphoric acid); and pig's urine, 25 per cent of solids (including 3 per cent nitrogen, 2 per cent potash and soda, and 0.125 per cent phosphoric acid).

In Cameron's 'Chemistry of Agriculture,' the following analyses are given :—

1000 PARTS OF ANIMAL EXCREMENTS CONTAIN—

	Cow.		Horse.		Sheep.		Pig.	
	Dung.	Urine.	Dung.	Urine.	Dung.	Urine.	Dung.	Urine.
Water, . . .	860	915	750	900	640	950	760	976
*Solid matters, .	140	85	250	100	360	50	240	24
	1000	1000	1000	1000	1000	1000	1000	1000
*Containing—								
Nitrogen, . .	3.6	9	6	11	6	8	7	3
Phosphoric acid, .	3	—	4	—	5	—	5	1.2
Potash and soda, .	2.2	16	3.5	14	3	8	6.5	2

Voelcker analysed the fresh dung of sheep fed upon roots placed on old pasture, and obtained the following results :—

100 parts contained—

Water,	73.13
* Organic matter,	20.28
Ash,	6.59
	100.00
* Containing nitrogen,	0.95
Equal to ammonia,	1.15

The urine of horses, cows, and sheep is very alkaline, and contains a large amount of *hippuric acid*, which is highly nitrogenous. Pig's urine is also alkaline: it contains urea, but not hippuric acid.

The amounts of urine and dung voided by the farm animals are variously estimated. Stöckhardt's estimates are as follows:—

Average Quantities of Excrements voided yearly by the

	Cow.	Horse.	Sheep.	Pig.
	lb.	lb.	lb.	lb.
Dung.	20,000	12,000	760	1800
Urine,	8,000	3,000	380	1200
Total,	28,000	15,000	1140	3000
Money value (in Germany),	£5, 14s.	£4, 10s.	10s. 6d.	13s.

Stöckhardt's estimates in the case of the cow are evidently too high; whilst Dr Thompson appears to be under the correct figures in giving the average annual amount of the dung of the cow at 3100 lb. Boussingault states that the average annual yield of urine from the cow is 6510 lb. Mr T. Baldwin of Glasnevin states that, from observations which he caused

to be made, he found that horses gave 12 lb. of urine daily—and cows, well fed, 70 lb.

In a trial made with different kinds of dung as a manure for barley, the following results were obtained, equal quantities of the manures being used :—

	Barley.		Barley.
Cow-dung, . .	167 lb.	Pig-dung, . .	233 lb.
Horse-dung, . .	226 ,,	Sheep-dung, . .	244 ,,

Bird's dung.—The bird voids but one excrement, which partakes more of the nature of urine than of fæces. It is a good manure, but it is not usually obtained in these countries in large quantities. The manure from the poultry-yard, such as it is, should be carefully gathered up and added to the compost-heap. The same observation applies to the dung of pigeons, which in some farmsteads is occasionally produced in large quantities. A specimen of pigeon's dung, collected fresh, and as free as possible from admixture with earthy matters, was found by Professor Anderson to contain :—

Water, ...	58.32
* Organic matter, ...	28.25
Phosphates, ...	2.69
Sulphate of lime, ...	1.75
† Alkaline salts, ...	1.99
Sand, ...	7.00
	100.00
* Yielding ammonia, ...	1.75
† Containing phosphoric acid, equal to phosphate of lime, ...	0.10

COMPOSITION OF DUNG OF BIRDS (ANDERSON).

100 parts contain—

	Hen.	Duck.	Goose
Water, ...	60.88	46.65	77.08
* Organic matter, &c.,	19.22	36.12	13.44
Phosphates, . .	4.47	3.15	0.89
Calcic carbonate, .	7.85	3.01	—
† Alkaline salts, . .	1.09	0.32	2.94
Sand, ...	6.69	10.75	5.65
	100.00	100.00	100.00
* Yielding ammonia, .	0.74	0.85	0.67
† Containing phosphoric acid, equal to tricalcic phosphate, .	0.07	trace	0.12

Boussingault has described pigeons' dung to be of extremely high value; but he analysed the article as imported in a dried condition from Egypt, and therefore more of the nature of guano than of dung.

In Flanders, the manure of 100 pigeons is considered to be worth 20s. a-year for agricultural purposes. In Catalonia, Aragon, and some other parts of Spain, pigeons' dung is sold as high as 4d. a pound, for applying, when mixed with water, to flower-roots, melons, tomatoes, and other plants. The estimation in which it was held in ancient Palestine may be inferred from the statement that, during a siege of Samaria, the fourth part of a cab of doves' dung was sold for five pieces of silver—2 Kings, vi. 25 That which is here translated *doves' dung* was, however, considered by Linnæus to mean the bulbous root of the *Ornithogallum umbellatum*, still eaten in Palestine, and forming part of the food of some of the tribes of Hottentots at the Cape of Good Hope.

Straw.—The straw (oat, wheat, and barley) which forms the bedding of cattle enters into the composition of most kinds of farmyard manure. It contains on an average about 5 parts of nitrogen, 10 of potash, and 3 of phosphoric acid, per 1000 parts. As from 2000 to 3000 lb. of straw are produced from an acre of a corn crop, this substance restores to the soil a considerable proportion of the fertilising matters extracted from it.

CHAPTER XXXI.

THE STORAGE AND APPLICATION OF FARMYARD MANURE.

Changes which Farm Manure undergoes in Storage.—Fresh farmyard manure generally contains about 70 per cent of water and 30 per cent of (dry) organic and earthy matters. Only a very small proportion of the dry matters consists of substances soluble in water. In a short time, however, the organic matters—straw, &c.—begin to ferment, one result of which process is the production of soluble compounds. Fresh manure produces but little effect when applied to crops; but when it is far advanced in decomposition (*i.e.*, well rotted), it then contains so much soluble matter absorbable by plants that it acts as a powerful fertiliser (if used in sufficient quantity).

In fresh manure, the most important constituent of

its soluble portion is potash; of phosphoric acid and ammonia it contains but very small proportions. Rotten manure, on the contrary, yields to the solvent action of water large amounts of nitrogen and phosphoric acid. If good fresh farmyard manure be dried at 212° F., the soluble organic matters of the residue will be found to amount to from 7 to 8 per cent, and its soluble mineral matters to from 4 to 5 per cent. On the other hand, dry rotten farmyard manure contains from 13 to 16 per cent of soluble organic matters, and 5 to 6 per cent of soluble mineral substances.

Dr Voelcker has shown that there is very little *free* ammonia in either fresh or old farmyard manure, and that the peculiar odour of the latter is not due, as popularly supposed, to the escape of ammonia from the manure. In the hot centre of a fermenting dung-heap some free ammonia is formed, but this is prevented from escaping by the cold outer layers of the manure, which act like a chemical filter.

Dr Voelcker, in a paper of great value, published in the 17th volume of the Royal Agricultural Society, gives the following summary of the changes which farmyard manure undergoes in storage:—

1. That during the fermentation of dung, the proportion of both soluble organic and soluble mineral matters rapidly increases.

2. That peculiar organic acids, not existing—at least, not in considerable quantities—are generated during the ripening of dung from the litter and other non-nitrogenised organic constituents of manure.

3. That these acids (humic, ulmic, and similar acids) form, with potash, soda, and ammonia, dark-

coloured, very soluble compounds. Hence the dark colour of the drainings of dung-heaps.

4. That ammonia is produced from the nitrogenous constituents of dung, and that this ammonia is fixed for the greater part by the humus substances produced at the same time.

5. That a portion of the sulphur and phosphorus of the excrementitious matters of dung is dissipated in the form of sulphuretted and phosphoretted* hydrogen.

6. That volatile ammoniacal compounds, apparently in inconsiderable quantities, escape into the air.

7. That the proportion of organic substances in fresh dung rapidly decreases during the fermentation of dung, whilst the mineral substances increase in a corresponding degree.

8. That this loss of organic substances is accounted for by the formation of carbonic acid, oxide of carbon, and light carburetted hydrogen, or marsh gas.

9. That the proportion of nitrogen is larger in rotten than in fresh dung (dry weights).

Loss of Fertilising Matters from Manure.—The experiments of Voelcker show that farmyard manure does not lose much by exposure to air, heat, and light. The deterioration which ill-kept manure-heaps undergo is therefore due to losses by drainage. The dark-coloured liquid which we too often observe trickling away from badly-kept dung-heaps is rich in nitrogen, phosphoric acid, and potash.

* It is not probable that phosphoretted hydrogen is given off during the decay of any kind of ordinary organic matter. Plösz and Hoppe-Seyler found that decomposing fish emitted sulphuretted hydrogen, but not phosphoretted hydrogen.—C. A. C.

Koerte found that 100 loads of dung kept in the usual wasteful manner were reduced at the end of—

	Loads.			Loads.
81 days to	73.3,	sustaining a	loss of	26.7
285 ,,	64.4,	,,	,,	35.6
384 ,,	62.5,	,,	,,	37.5
499 ,,	47.2,	,,	,,	52.8

Thus in sixteen months more than one-half—and that the most valuable portion—of the manure had disappeared, leaving a highly carbonaceous matter, poor in all the elements of fertility.

Voelcker analysed a specimen of pig-dung which a farmer had kept for three years in the expectation of converting it into an excellent turnip-manure. It was greasy, black, and had an earthy rather than an animal odour. 100 parts contained—

Water,	73.66
*Soluble organic matter,	2.70
†Insoluble organic matter,	9.95
‡Soluble inorganic matter,	2.68
Insoluble inorganic mater,	11.03
	100.00
*Containing nitrogen,	0.157
†Containing nitrogen,	0.470
	0.627
‡Containing calcic phosphate,	0.577
And potash,	0.376
Containing phosphoric acid (equal to calcic phosphate, 1.176),	0.543
And potash,	0.317
Total nitrogen (equal to ammonia, 0.770),	0.627
Total calcic phosphate,	1.753
Total potash,	0.693

It seems certain that at least half the amount of fertilising matter contained originally in this dung was lost by keeping the manure too long.

Application of Farmyard Manure. — Instead of keeping farmyard manure for months or years in heaps, exposed to rain, as is too often the case, Voelcker recommends its immediate application to the soil; that is, whenever the conditions of labour, &c., on the farm admit of it, the manure should be carted out to the field, and either put into the soil at once or spread over it. In the latter case, no loss of any consequence would be sustained by evaporation; whilst the soluble matters would, if rain fell, be merely washed into the soil, in which they would be securely retained until required by the crop. Voelcker appears to consider that it is better to let the rain wash the soluble matters into the soil in a uniform manner, than to plough in the fresh manure at once. He believes that on clay soils manure may be safely spread for six months before it is ploughed in; but of course on very porous sandy soils it is preferable to apply the manure, previously well fermented, shortly before the time it is required for the crop.

Manure made under Cover.—Manure produced by cattle in boxes, and afterwards kept under cover, is much superior to ordinary farmyard manure. Lord Kinnaird experimented with the manure produced from a certain number of animals under cover—and from a like number of animals of the same kind and age, and fed similarly, kept in an open yard,—and obtained the following results :—

Manure produced under cover.	Manure not produced under cover.
1st year, potatoes = 11¾ tons per acre.	1st year, potatoes = 7 tons 12 cwt. per acre.
2d year, wheat = corn, 54 bush.; straw, 215 stones.	2d year, wheat = corn, 42 bush.; straw, 156 stones.

Manure made under cover owes its richness to the circumstance that less straw is required to bed the cattle, and also that the urine of the animals, which in open yards is chiefly wasted, is almost altogether preserved in the box-made manure. Mr Way analysed manure made in boxes on Mr Charles Laurence's well-known farm near Cirencester, and found its composition to be as follows:—

100 parts contained—

	Box manure.	Ordinary Farmyard manure.
Water,	71.40	71.00
*Dry matter,	28.60	29.00
	100.00	100.00
*Containing nitrogen, equal to ammonia,	2.37	1.70
Phosphoric acid,	0.30	0.26
Potash and soda,	2.00	0.80

Manure - Drainings.—The dark - coloured liquid which trickles out of manure-heaps has been analysed by Voelcker. He found one imperial gallon (70,000 grains) to contain 1357.74 grains of solid matters; including nitrogen, 31.08 grains—phosphates of calcium and iron, 72.65 grains—and carbonate and chloride of potassium, 358.02 grains. In other instances Voelcker found from 353.36 grains of solids to 764.64 grains per gallon.

The older farmyard manure is, the more soluble will it be, and consequently the more liable to deterio-

ration by exposure to rain. Perfectly fresh manure does not lose much by the action of rain upon it, especially if it be stored in large quantity.

The drainings from manure-heaps, and animal manures generally, should not, when stale, be mixed with quick-lime, because that substance would cause them to lose, though not largely, ammonia. If they have to be kept for a considerable time, the addition of a little gypsum will be found useful. Liquid manure, especially when diluted, loses, however, but little valuable matter by evaporation.

Liquid-Manure Tank.—Every farmstead should be provided with at least one tank for the storage of liquid manure. Into this all the sewers or drains from stables, privies, laundries, &c., should empty their contents. If this were always done, there would be fewer cases of foul water being drunk by the dwellers in houses near farmsteads. The shafts of the pumps near the houses of farmers, too often collect the sewage, which, if proper provision had been made, should have gone into the liquid-manure tank. Water contaminated with decomposing animal matter is a common cause of disease, and this polluted water is very often that which is alone used by the farmer and his family.

Deep tanks for the storage of liquid manure are not, as a rule, desirable, as it is difficult to prevent their contents from leaking out. From 6 to 7 feet will be sufficient depth, or even less, when the land is unfavourably circumstanced with regard to drainage. To save expense in arching, the width need not exceed from 6 to 8 feet; but the capacity of the tank may be secured by extending the length of it

Dissolved Peruvian Guano.—Messrs Ohlendorff & Co., of London and Hamburg, have recently introduced a manure, prepared by treating Peruvian guano with sulphuric acid. By this process the bone phosphate and guanine are rendered soluble, and the organic matter is so much altered in composition that it decomposes more readily in the soil, and is therefore in a more immediately available form to meet the wants of the crop. We have found the composition of a specimen of this manure to be as follows:—

COMPOSITION PER 100 PARTS OF DISSOLVED PERUVIAN GUANO.

Moisture,	17.06
Organic and volatile matters,	51.50
(Including nitrogen equal to ammonia,	12.06)
Tetrahydric calcic phosphate,	14.52
(Equal to bone phosphate made soluble,	22.65)
Tricalcic (bone) phosphate,	3.40
Alkaline salts,	4.60
Calcic sulphate,	7.82
Insoluble matters,	1.10
	100.00

Dissolved Peruvian guano is a fine powder, is of uniform composition, and its constituents appear to be in a somewhat higher degree of effectiveness than are the ingredients of the unmanufactured guano.

African Guano, &c.—Cargoes of guano are occasionally imported into the United Kingdom from Africa and various parts of America. In the following table are given analyses of four of those guanos, as they are at present of some commercial importance:—

COMPOSITION OF GUANO.

100 parts of each contain—

	Mejillones.	Ichaboe	Penguin Island.	Patagonian
Water, . .	8.98	18.60	26.83	23.00
Organic matter, &c.,	8.36	47.84	30.00	26.50
(Yielding ammonia,	0.75	13.00	6.60	4.10)
Calcic phosphate,	71.16	10.86	23.99	40.54
Calcic carbonate,	4.30	3.44	5.40	2.00
Alkaline salts, .	3.34	10.90	5.45	5.66
Insoluble matters,	3.86	8.36	8.33	2.30
	100.00	100.00	100.00	100.00

Mejillones guano is simply a phosphatic mineral. It is sometimes used alone, as its mechanical condition adapts it for equable distribution throughout the soil, and its phosphates appear to be somewhat soluble. It is often mixed with sodic nitrate, and sold in that condition to the farmer. There is not as yet sufficient evidence to enable us to form an opinion as to the value of the manure used alone; as to its efficacy when subjected to the action of sulphuric acid, there can be no doubt.

Value of Guano as a Fertiliser.—Mr Lawes says of Peruvian guano, that it is one of the best artificial manures for wheat; for which purpose 2 or 3 cwt. per acre, sown broadcast before the seed, and harrowed into the soil, will be found a sufficient quantity. Voelcker found that 2½ cwt. of Peruvian guano, costing £1, 12s. 6d., gave an increase of 12$\frac{1}{10}$ bushels of grain, and of 8 cwt. of straw, when used with a wheat crop. Mixed with superphosphate, it has been found a most valuable top-dressing for permanent pasture; and, with or without superphosphate, it constitutes an excellent manure for green crops and

potatoes. Peruvian guano is without doubt the most valuable auxiliary manure which the farmer possesses, and it resembles in the complexity of its composition farmyard manure, more than any other purchased manure does.

CHAPTER XXXIII.

BONES AND OTHER PHOSPHATIC MANURES.

Bones.—If a fresh bone be placed in a hot oven for some hours, it will be found to lose a considerable amount of its weight: the loss is occasioned by the evaporation of water. If the dried bone be next burnt in such a way that anything it may leave can be collected, it will be found that it loses a still larger proportion of its weight. This further loss is caused by the destruction of the organic portion of the bone. The organic portion consists chiefly of *bone cartilage*, or *ossein*, a substance closely resembling gelatin; that obtained from the bones of the ox is, according to Von Bibra, composed of,—carbon, 50.13; hydrogen, 7.07; nitrogen, 18.45; oxygen, 24.35 = 100. This is exclusive of a small quantity of sulphur. Ossein is insoluble in water, but by continuous boiling it is converted into gelatin, which dissolves readily in water. Ossein and gelatin are valuable fertilisers, and to their action the manurial effect of bone is in great part due. Good bones, when dried, yield about 4½ per cent of ammonia.

Von Bibra states that bone varies somewhat in composition according to the nature and sex of the animal; but this is denied by Fremy. Zaleski asserts that the relative proportions of organic and inorganic matter vary very slightly in the case of man and of the inferior animals. The results of numerous experiments gave the following results :—

	Man.	Ox.	Guinea-pig.
Organic matter,	34.56	32.02	34.70
* Inorganic matter (ash),	65.44	67.98	65.30
	100.00	100.00	100.00
Containing per cent—			
Carbonic dioxide,	5.734	6.197	...
Phosphoric acid,	39.019	40.034	40.381
Chlorine,	0.183	0.200	0.133
Fluorine,	0.229	0.300	...
Lime,	52.965	53.887	54.025
Magnesia,	0.521	0.468	0.485

The bones of birds contain from 68 to 76 per cent of ash, and those of fishes from 50 to 60 per cent. The bones of herbivorous animals and birds contain a larger proportion of lime than is found in the bones of reptiles and of flesh-eating animals. In cartilaginous fishes—such, for example, as the lamprey—the amount of earthy matters is very small. The manurial values of the bones of horses, oxen, and sheep do not differ in any important degree.

The composition of the calcic phosphate ("bone phosphate") has not been satisfactorily ascertained. It is usually regarded as tricalcic diphosphate = $Ca_3 2PO_4$. C. Aeby analysed fossil ivory and other bones in which the organic matter had naturally decayed, leaving the calcic phosphate in a favourable condition for examination. This he found to consist

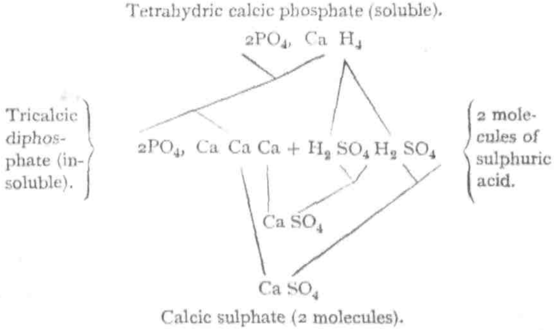
of $Ca_3 2PO_4$, together with a molecule of water, one-third of a molecule of lime, and one-sixth of a molecule of carbonic dioxide.

Fermented Bones.—The larger bones are, the longer do they remain in the soil without being completely decomposed. It therefore appears to be more economical to grind them into powder before using them. As it requires powerful machinery to grind bones, it may be found expedient to try some other process for hastening their manurial action. A good plan is to ferment them. This may be effected by mixing them with one-third of their weight of clay, saturating the compost with urine, and covering the mass with damp clay to the depth of 2 or 3 inches.

In an experiment made by Mr Pusey (whilom President of the Royal Agricultural Society of England) with 8½ bushels of fermented bones (costing £1, 0s. 9d.) and 17 bushels of ordinary bones (costing £2, 6s. 9d.) as manure for turnips, equal amounts of produce—13¼ tons per acre—were obtained. In a second experiment, £1, 11s. worth of fermented bones produced 17 tons 1 cwt. of turnips per acre; whilst £3, 10s. worth of unfermented bones yielded only 14¼ tons of produce.

On the farm of Sir Charles Coote, in Queen's County, on that of Mr Glascott, Priesthaggard, county of Wexford, and on many others, experiments with fermented bones as a turnip-manure have given highly satisfactory results. Large bones, no doubt, are *lasting* manures, their effects being produced during many years; but it is not economical to apply a manure a portion of which will produce no effect for perhaps a dozen of years.

Superphosphate of Lime.—About half-a-million tons of manufactured manures containing a soluble calcic phosphate are annually sold in the United Kingdom. The manure termed "superphosphate of lime" was at first made by acting upon bones by oil of vitriol; but it is now almost altogether prepared by mixing sulphuric acid with bone-ash, bone-black, and various mineral or native phosphates. In all these phosphates there exists tricalcic phosphate to the extent of from 45 to 75 per cent. This substance is very insoluble in water, and in the case of the mineral phosphates, its value as a manure is very trifling. By acting upon a molecule of tricalcic di-phosphate by means of two molecules of sulphuric acid, the former loses two atoms of calcium, which are replaced by four atoms of hydrogen. The new phosphate is very soluble in water, and hence its value, as we shall see further on. The changes which take place in converting insoluble into soluble phosphate are as follows:—



or $Ca_3 2PO_4 + 2H_2SO_4 = CaH_4 2PO_4 + 2CaSO_4$

According to Armsby ('American Journal of Science,' July 1876), *one* molecule of sulphuric acid acting upon *one* molecule of tricalcic phosphate, produces, with one-half of the phosphate, tetrahydric calcic phosphate, which, slowly acting upon the other moiety of phosphate, produces dihydric dicalcic phosphate—$H_4Ca2PO_4 + Ca_32PO_4 = 2H_2Ca_22PO_4$.

There are three kinds of sulphuric acid met with in commerce—namely, *white* (specific gravity, 1.845°), *brown* (specific gravity, 1.700°), and *chamber* (specific gravity, 1.450°). It requires 64 lb. of white, 82 lb. of brown, and 114 lb. of chamber, acid to convert 100 lb. of insoluble phosphate into soluble phosphate. If, therefore, bones or a native phosphate containing say 50 per cent of tricalcic phosphate be perfectly converted into soluble phosphate, it will use up 41 per cent of its weight of brown acid, or 32 per cent of white acid. As, however, the bones or other phosphatic materials invariably contain calcic carbonate, this compound will use up a portion of the acid—thus $CaCO_3 + H_2SO_4 = CaSO_4 + CO_2 + H_2O$. Every pound of calcic carbonate in the raw material will use up, or rather almost waste, its own weight (strictly, 0.9816 per cent) of white, 1¼ lb. of brown, and 1¾ lb. of chamber acid. The mineral phosphatic materials invariably include small quantities of alumina and oxide of iron, which unite with sulphuric acid, and produce sulphates of aluminium and iron; 100 lb. of raw phosphate may in this way waste from 4 to 2 lb. of sulphuric acid. Knowing, then, the composition of his raw material, and the strength of his acid, the manufacturer can determine the exact quantity of the latter to add to the former.

Manufacture of Superphosphate.—In artificial manure works, the raw phosphate (reduced to powder between millstones) is placed in a close vessel called a *mixer*, and the necessary quantity of acid is let down upon it from a tank, through a kind of hopper. The gases evolved from the mixture are chiefly carbonic dioxide, hydrofluoric acid (HF), and fluoride of silicon (SiF_4). It is alleged that arsenical vapours are also given off; but of this there is some doubt. It is, however, desirable that the vapours and gases from the mixer should not be directly discharged into the atmosphere; they should be carried through a long flue, provided with numerous fine jets of water, which would condense the dangerous portion of the volatile matters.

When the acid is let down upon the phosphate, the solid and liquid are intimately mixed by means of a strong spindle provided with four blades, placed at right angles. In a short time the bottom of the mixer is opened by means of a lever, and the contents—usually from 10 to 20 cwt.—fall on the ground of a close chamber called a *den*. The different batches of superphosphate thus made are afterwards put through a Carr's disintegrator, and stored for some time, and finally put into bags for sale.

Superphosphate is occasionally made by the farmer; but there is no economy to be effected in this way, as he is obliged to buy sulphuric acid * from the vitriol-maker, and to use bones, which are a very expensive material. If the farmer have bones

* It is well known in the manure trade that most of the profit made by the manufacturer of superphosphate is in the production of sulphuric acid. In selling his superphosphate, he is in reality making a profit almost solely upon his acid.

available, his best plan is to ferment or grind them, and to add them to a purely mineral superphosphate, which he can purchase very cheaply. If, however, the farmer decides to become his own artificial-manure maker, he should proceed as follows: Provide a wooden trough, 12 feet long, 4 feet wide, and 1½ foot deep. Protect its interior from the action of the acid by a coat of pitch. Spread over the bottom of this vessel, the bones, &c., to be vitriolised, and add about one-third of their weight of water; next pour uniformly over them half their weight of brown acid, or one-third of their weight of white acid; mix quickly with a wooden spade, and let the mixture stand for an hour or so. The manure may then be removed to a covered shed and kept until required, which should not be for a month or two at least.

As the cost of the carriage of oil of vitriol from one place to another is sometimes considerable, it may under certain circumstances be found more economical to use the white acid, though it is the dearest. One pound of white sulphuric acid is equal to 1¼ lb. of brown acid, and 1¾ lb. of chamber acid.

It is regretable that in the manufacture of ordinary mineral superphospates, all the insoluble phosphate is not converted into soluble phosphate; in general from one-sixth to one-third remains unaltered. The proper plan would be to thoroughly "dissolve" the mineral phosphate and to "dry" the damp superphosphate thereby produced with fine bone-meal, or that failing, with gypsum. The following is the composition of a superior mineral superphosphate:—

100 parts contain—

Water,	15.00
Organic and volatile matters,	12.00
* Monocalcic phosphate,	18.00
Insoluble phosphate,	6.00
Calcic sulphate,	41.95
Alkaline salts,	0.55
Insoluble matters,	6.50
	100.00

* Equal to calcic phosphate made soluble by acid, 28.28

"Biphosphate of lime" is very often the term used for "monocalcic phosphate," in the statement of the analysis of a superphosphate. Neither term is correct; for the substance produced by acting upon insoluble phosphate with sulphuric acid is, *tetrahydric calcic diphosphate.* Formerly this substance was regarded as a compound of one molecule of lime with one of phosphoric acid; it was termed "biphosphate of lime," and assigned the formula — $CaO + PO_5$. Now, 100 parts of this compound corresponded to 156 parts of insoluble phosphate (by old notation, $3CaO + PO_5$). Chemists still state that 1 per cent of monocalcic phosphate equals 1.56 per cent of "phosphate made soluble," meaning thereby that 1.56 parts of the insoluble are required to produce 1 part of the soluble. When a manure is said to contain 20 per cent of soluble phosphate, it implies, not that it contains that amount of monocalcic phosphate ("biphosphate of lime"), but that the soluble phosphate present had been produced from 20 per cent of insoluble, or "bone," phosphate. In reality, one part of soluble phosphate is equal to only 1.33 parts of insoluble phosphate, or to 0.85 per cent of "biphosphate."

Reduced Phosphates.—In many superphosphates the amount of soluble phosphate decreases from 1 to 5 per cent, when the manure is kept for some months. This circumstance often leads to disputes and litigation between the sellers and buyers of artificial manure. There are differences of opinion as to the cause or causes of this "going back," of the soluble phosphate. Some chemists believe that the insoluble phosphate is produced by a molecule of insoluble phosphate reacting upon one of soluble, and producing therewith two molecules of dihydric dicalcic phosphate ($Ca_3 2PO_4 + H_4 Ca 2PO_4 = 2H_2 Ca_2 2PO_4$). The phosphate of calcium thus formed, though not so insoluble as bone-earth, is still comparatively insoluble. Other chemists contend that it is the oxide of iron and alumina in the manure which gradually combine with a portion of the phosphoric acid of the soluble phosphate, and produce insoluble calcium, iron, and aluminium phosphates. This is the more probable conjecture; though it appears strange that in superphosphates the oxide of iron and alumina should escape being dissolved, whilst the phosphate and fluoride of calcium are decomposed by the oil of vitriol. In some minerals, however, alumina and iron oxide are not readily dissolved by acids. When superphosphate is put into the soil, its soluble is immediately converted into insoluble phosphate, by the action of the lime which is sure to be present. If we suppose that this effect is produced by calcic carbonate the change would be as follows: $H_4 Ca 2PO_4 + 2CaCO_3 = Ca_3 2PO_4 + 2CO_2 + 2H_2O$. The alumina, oxide of iron, and magnesia of soils may also, especially in the absence of lime, produce precipitates.

The precipitated phosphate assumes the form of a jelly, and if there be sufficient moisture in the soil (*i.e.*, if the weather be wet at the time), it is surprising how large a quantity of gelatinous matter is produced from a cwt. of good superphosphate. This soft mass of phosphate dissolves readily in the water containing carbonic acid, salts of ammonia, &c., present in the soil, and in these menstrua it is carried up into the organs of the plants.

Mineral and Bone Phosphates.—Phosphoric acid in combination with calcium, magnesium, aluminium, and iron, is widely diffused throughout the crust of the globe, and in some localities is found in large quantities, constituting an article of commercial importance, The following are some of the more important mineral phosphates which are used in the artificial manure industry.

Coprolites are grey, hard, nodular masses found in the upper greensand of Cambridgeshire and in some other localities. They are believed to be fossilised bones of extinct races of animals. They contain in general about from 52 to 60 per cent of earthy phosphates, 12 to 18 per cent of calcic carbonate, 4 or 5 per cent of alumina and oxide of iron, 2 to 3½ per cent of fluoride of calcium, and 6 to 9 per cent of sand. A brown variety, termed *pseudo*, or *false* coprolites, is found in Suffolk, Bedfordshire, and Buckinghamshire; they consist of a mixture of fossilised bones and dung of extinct animals, and are somewhat inferior to the Cambridge coprolites, on account of their larger percentage of alumina and iron oxide, and smaller proportion of phosphoric acid. They contain from 45 to 55 per cent of calcic phosphate,

from 10 to 18 per cent of calcic carbonate, and from 7 to 12 per cent of alumina and iron oxide. "Boulogne coprolites" resemble Suffolk coprolites; but another phosphatic mineral obtained from France, under the name of "Lot" phosphate, is nearly white, includes from 65 to 80 per cent of calcic phosphate, and produces a very concentrated superphosphate.

Navassa guano obtained from Hayti occurs in brown lumps and reddish powder. Its calcic phosphate varies from 45 to 57 per cent, its calcic fluoride from 1 to 2 per cent, its calcic carbonate from 4 to 7 per cent, and its iron oxide and alumina from 10 to 12 per cent. It also includes rather large amounts of aluminic phosphate. It is very abundant, but it does not appear to be a good raw material for the manufacturer, on account of its large proportion of iron and aluminium compounds.

Charleston phosphate is now largely imported from the United States. It is highly fossiliferous, varies in colour from grey to fawn in the case of the variety termed "land phosphate;" whilst the "river phosphate" is almost black. The latter contains from 50 to 60 per cent calcic phosphate, 12 to 14 per cent calcic carbonate, 3 to 4 per cent iron and aluminium oxides, 12 to 16 per cent sand, and 1 to 3 per cent calcic fluoride. It is not easy to grind this mineral, but it is readily dissolved by acid.

Sombrero phosphate is not now imported in quantity. It contains about 70 per cent of phosphates.

Orchilla guano contains about 45 per cent of calcic phosphate and nearly 20 per cent of calcic carbonate; it is not, therefore, suited for making superphosphate.

German phosphate, which is a variety of the mineral

termed *phosphorite*, contains from 60 to 75 per cent of calcic phosphate, from 3 to 5 per cent of calcic carbonate, and from 6 to 12 per cent of alumina and oxide of iron. It is one of the best materials now available for the manufacture of concentrated superphosphate. Shaw's Island, Baker's Island, and Howland's Island, contain each about 60 to 65 per cent of calcic phosphate.

Estremadura phosphate is obtained from Spain and Portugal. It includes from 70 to 80 per cent of calcic phosphate, from a trace to 8 per cent of calcic carbonate, a trace of fluoride of calcium, 2 to 8 per cent of oxides of iron and aluminium, and from 2 to 12 per cent of silicious matters.

Apatite is the mineral which constitutes the *Canadian* and *Norwegian phosphates.* The latter contains from 70 to 90 per cent of calcic phosphate, from 1 to 4 per cent of calcic chloride, and from 3 to 10 per cent of sand, iron oxide, &c. Canadian apatite includes from 80 to 90 per cent of calcic phosphate, from 0.5 to 1 per cent calcic chloride, 6 to 9 per cent calcic fluoride, and 2 to 6 per cent of sand, &c. For manure-making, the Norwegian phosphate is best, owing to its freedom from calcic fluoride.

There are large quantities of phosphatic minerals, but of poor quality, in Wales.

Bone-ash is imported in large quantities from South America, where it is produced by calcining ox-bones. It includes from 67 to 73 per cent of calcic and magnesic phosphates, 7 to 10 per cent of calcic carbonate, 1 per cent of alkaline salts, and the rest is made up of water, charcoal, silica, &c. It produces a concentrated but damp superphosphate of great value.

roots; but if there be abundance of dung available, from 3 to 4 cwt. will be sufficient. If no farmyard dung be used with the root crop, then the following crop should be specially manured, and, if possible, with a fertiliser rich in organic matter. It is desirable to mix superphosphate with two or three times its bulk of ashes, mould, or fine clay, before applying it. When this manure (or any other into the composition of which it enters) is applied as a top-dressing to grass or clover, showery weather should be selected, as the rain will wash the soluble part equably into the soil.

CHAPTER XXXIV.

HUMAN EGESTA AND TOWN SEWAGE.

Human Egesta. — The average amount of solid excrement voided by a human being, averaging both sexes and all ages, is about 3 oz. per day = nearly 31 lb. yearly; and of urine, 2 lb. = 730 lb. yearly. The solid excrement consists of woody fibre, undigested food, fatty, waxy, and resinous substances, together with phosphates of calcium and magnesium, and various earthy and saline matters. Wehsarg found fæces to consist of 73.3 parts of water, and 26.7 parts of solid matters; whilst Berzelius states that they are composed of 75.5 parts of water, and 24.5 parts of solid matter. About 5 or 6 per cent of fæces consist of mineral matters, or ash. According

to Porter, this ash contains 6.1 per cent of potash, 5.07 per cent of soda, 26.46 per cent of lime, 10.54 per cent of magnesia, 36.03 per cent of phosphoric acid, 1.33 per cent of common salt, and 11.47 per cent of oxide of iron, sulphuric acid, &c. = 100.

Urine varies considerably in composition, some specimens containing 3 per cent of solid matters, whilst others yield from 4 to 6 per cent. It contains a large amount of urea (page 260), and a small proportion of other nitrogenous bodies. It also includes phosphoric acid, potash, and soda.

There are great discrepancies in the statements published in reference to the value of human excrements as a manure, some authorities estimating those of one person to be worth annually from 7s. 6d. to 15s. We believe that the following figures are tolerably near to the truth, inclining, however, to an under rather than an over estimate of the money value of *excreta*, and of the quantities voided annually.

Amount of nitrogen, phosphoric acid, and potash yearly voided by an average unit of the population :—

	Pounds weight.	Money value. *s.*	*d.*
Nitrogen, ...	10⅚	5	3
Phosphoric acid, ...	2¼	0	3⅜
Potash, ...	2	0	4

Mr Lawes estimates the value of the *excreta* of an average unit of the population at 7s. 6d. for 10½ lb. ammonia, 9d. for 4½ lb. of phosphates, and other matters, 7d.—total, 8s. 10d.

Human excrements are highly valued in China, where they are preserved, and applied with great economy. In Belgium, too, not only do the farmers use up the

nightsoil, &c., produced on their farms, but they contract with persons to have the contents of the cesspools of the nearest town brought regularly to them. To retain these matters until required for use, they construct very substantial and expensive liquid-manure tanks. When required, the liquid manure is pumped up from its underground receptacle, and distributed uniformly—so many gallons to so many square yards—over the land.

Poudrette.—In many Continental towns the nightsoil is collected, dried, and converted into a manure termed *poudrette*. Sometimes it is mixed with gypsum or other substances, for the purpose of disguising its odour. Poudrette is in general manufactured in a very unscientific manner, and is seldom worth the price (£3 to £4 per ton) at which it is sold. It rarely contains more than 2 per cent of nitrogen, and frequently only 1 per cent, together with 3 per cent of calcic phosphate, and 1.5 per cent of potash.

The attempts to evaporate urine nearly to dryness, so as to produce from it a portable manure, have proved failures. The cost of evaporation was considerable, and there were difficulties in the way of collecting and conveying the liquid. The manure termed *urate* is now *not* prepared from urine, but is merely a mixture of superphosphate and nitrogenous matters.

Where earth-closets are used, the mixture of excrements and earth produces a good fertiliser, but one which is not sufficiently valuable to bear the cost of carriage to a greater distance than five or ten miles. If charcoal were used as a substitute for the earth, the manure produced would be more valuable.

Voelcker's and Gilbert's analyses of earth-closet manure have shown that it possesses but little value.

Town Sewage.—By far the greater portion of the *excreta* of the inhabitants of towns passes into sewers, from which it is discharged into rivers or the sea. The urine of the immense number of horses, cows, and other animals in towns is chiefly disposed of in a similar manner. The loss of fertilising matter in this way is enormous, and is constantly on the increase, owing to the extension of water-closets and main sewers. Not only is there a waste of valuable manure in this way; but the removal of fæces, urine, and waste-matters of various kinds by water-carriage, has resulted in the pollution of the rivers of a large portion of the United Kingdom. These rivers are no longer fit sources of potable water, and many of them evolve noxious exhalations, which no doubt must have a prejudicial effect upon the public health.

The large proportion of the *excreta* of the denizens of towns which is discharged into drains and rivers may be inferred from the smallness of the quantity sent out in the form of town manure, as shown in the Report of the Rivers Pollution Commission for 1870:—

QUANTITY AND VALUE OF TOWN MANURE.

Name of Town.	Population using privies.	Tons of manure annually.	Money received.	Value per head.
			£	d.
Liverpool . .	350,000	138,777	8,000	5.5
Widness . . .	12,000	1,800	150	3.0
Salford . . .	120,000	38,600	4,000	8.0
Manchester . .	300,000	73,594	6,740	5.4
Bolton . . .	75,000	22,465	1,567	5.0
Bury . . .	29,000	7,000	100	0.8
Oldham . . .	77,000	50,000	2,000	6.2
Ashton-under-Lyne	37,000	6,637	95	3.2
Southport . .	15,000	9,000	740	8 8
Total . .	1,015,000	347,873	23,392	5.5

Composition and Money Value of Sewage.—Town sewage varies considerably in composition, the variation chiefly resulting from the local conditions under which the towns are placed. The rainfall, the supply of pipe-water, the number of water-closets, the nature of the manufactories, and many other factors, determine the composition of the sewage.

100 TONS OF THE SEWAGE OF DUBLIN CONTAIN THE FOLLOWING FERTILISING INGREDIENTS :—

1st, In complete solution—						
Nitrogen, .	16.50 lb. at	£70 per ton,	£0	10	3.75
Phosphoric acid,	3.85 "	40 "	0	1	4.50
Salts of potassium,	5.12 "	20 "	0	0	10.97
Salts of sodium,	16.63 "	1 "	0	0	1.78
		Total,	£0	12	9.00
2d, Mechanically suspended—					
Nitrogen, .	2.48 lb. at	£70 per ton,	£0	1	6.60
Insoluble calcic phosphate, .	1.84 "	8 "	0	0	1.57
Organic matter,	14.00 "	0 10 "	0	0	0.75
		Total,	£0	1	8.92
		Grand total,	£0	14	5.92

The money value here placed upon sewage is, however, based upon the supposition that its ammonia, phosphoric acid, &c., are as useful as if they were in the form of guano. So they would be, if the sewage in limited quantity and at the proper time were applied to the soil; but town sewage is in most instances collected in a very expensive manner, is distributed over the land during the whole year, and is usually applied in quantities far greater than is necessary for the wants of at least most crops. In valuing the sewage obtained from a town of large size, any sum over 1½d. per ton will be excessive.

Application of Sewage.—This manure has been applied to every kind of field crop, and has been employed by market-gardeners; meadows, however, have up to the present been most benefited by its use. A portion of the sewage of the Old Town of Edinburgh has for many years been used as an irrigant, especially on the meadows at Craigentinny. These are let to cow-keepers at an average rent of about £26 a-year. From three to five heavy crops of grass are annually obtained, though the summer is a short one in the "Modern Athens."

Mr Hope, of Lodge Farm, Barking, has produced with sewage 10 crops of Italian ryegrass (of about 9 or 10 tons each) in a single year!

In 1861 a Royal Commission was appointed to experiment on the sewage of Rugby. The object was to determine the quantity and composition of grass produced on land, a portion of which was to be manured with sewage, and another portion to remain unmanured. Fifteen acres were divided into three equal parts—one for grass on which cows were to be

fed, another for grass on which oxen were to be fed, and the third was to be meadowed. Each of these five-acre divisions was further subdivided into four plots, one of which was left unmanured, and the others received respectively different quantities of sewage. Some of the results obtained are tabulated in the following table :—

PRODUCE GIVEN TO OXEN.

Plot.	Sewage required per annum.	Actually applied to end of October.	Total grass per acre.				Increase of grass per 1000 tons of sewage.			
			tons	cwts.	qrs.	lb.	tons	cwts.	qrs.	lb.
1	...	...	9	5	3	5	...	...	...	...
2	3,000	1,872	14	16	3	8	2	19	1	7
3	6,000	4,423	27	1	0	10	4	0	1	9
4	9,000	6,153	32	16	3	8	3	16	2	9

On the grass given to the milch-cows the effects of the sewage were still more favourable, as will be seen in the following table :—

PRODUCE GIVEN TO MILCH-COWS.

Sewage applied.	No. of weeks the produce kept a cow.	Gallons of milk per acre	Value of milk at 8d. per gallon.			Value of milk from increased produce of 1000 tons sewage.		
			£	s.	d.	£	s.	d.
...	19.0	321.0	10	14	3	5	0	0
1,387	40.9	570.7	19	0	6	5	19	10
2,804	58.8	820.4	27	6	11	5	16	8
4,226	68.9	961.3	32	0	10	5	0	11

In these trials it is shown that the application of vage was attended by a very great increase in the

produce of grass. "Deducting the value of the milk from the grass of the unsewaged from that of each of the sewaged acres, reckoning it at 8d. per gallon, it appears that where about 1400 tons of sewage were applied, during the seven months, the produce calculated for each 1000 tons of sewage actually applied gave an increased amount of milk to the value of £5, 19s. 10d.; where twice that amount of sewage was applied, £5, 18s. 8d.; and where three times the quantity, £5, 0s. 11d." The value of the milk obtained from an acre of unsewaged grass was only £10, 14s. 3d., whilst from the most highly sewaged grass the value of the milk amounted to no less than £32, 0s. 10d. The Rugby experiments, which were conducted under the direction of Mr J. B. Lawes, have been considered somewhat unsatisfactory, on the ground that the sewage was not always applied at the proper time; and Mr Walker states that the fields were flooded to such an extent as to seriously deteriorate the quality of the herbage. Mr Lawes admits that the experiments were in some respects so conducted that their results would not appear so favourable to the sewage as under proper conditions would have been the case; but still the great fact remains that land abundantly sewaged is capable of producing three times as much milk as the same kind of land when unsewaged.

The sewage wholly or in part of many towns, is or has been used for agricultural purposes. In some instances it is stated to have been successful; but in most cases it has proved a failure, financially at least.

The sewage of Paris is now in part used for irrigation, and it has been decided to apply the whole of

fed, another for grass on which oxen were to be fed, and the third was to be meadowed. Each of these five-acre divisions was further subdivided into four plots, one of which was left unmanured, and the others received respectively different quantities of sewage. Some of the results obtained are tabulated in the following table :—

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2	3,000	1,872	14	16	3	8	2	19	1	7
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it in that way. Only about 1 in every 10 houses in Paris is, however, in connection with the main sewers.

Soils suitable for Sewage. — Light or medium soils resting on a sandy subsoil will be found the best absorbents of sewage, although their power of retaining the fertilising ingredients is not so great as that of heavy clays. On stiff clay lands, the chief fault of which is their impertransible nature, large dressings of town sewage would not be beneficial—nay, would be the reverse: the fluid would rest on the surface, and render the soil so cold and wet as to be decidedly injurious to most plants. Land of any kind under cereals cannot constantly be the scene of sewage irrigation; for during the long period of the year devoted to the preparation of the ground, a dry and easily pulverulent condition of the staple is desirable—and during the ripening of the crop, heat and a very moderate degree of humidity are necessary. It is clear, then, that cereal crops could only be benefited by very moderate doses of sewage applied at only certain periods of the year. Still, where sewage is available, we believe that both white and green crops would be largely served by its use; and if it were in a more concentrated condition than that derived from large towns is, it might be applied during by far the greater part of the year.

Chemical Treatment of Sewage.—Probably about sixty patents have been taken out in reference to the preparation of portable manures from sewage. The general method adopted was to add to the manure such substances as "superphosphate of lime," crude aluminic sulphate, mineral phosphates, &c. The A B C process (which got an extensive trial) con-

sisted in adding alum, blood, clay, and charcoal to the manure. The resulting precipitate, collected and dried, constituted the "native guano" of which we have heard so much. Although it was shown that the money value of the native guano was less than that of the materials from which it was produced, there are chemists who still consider this process as one likely yet to produce good results financially.

The difficulties in the way of precipitating a really good manure out of town sewage are,—first, the small quantity of fertilising matter in it; second, the fact that by far the most valuable portion of the sewage, namely, its urea, cannot be precipitated; and third, the high cost of the precipitants. Certainly the manures hitherto made from sewage appear to have had very low values, generally not exceeding £2 per ton.

So far as our present knowledge permits us to judge of the vexed subject of sewage utilisation, filtration through soils is the process which appears the simplest and most practicable. A combined system of precipitation and filtration is not admissible, for ordinary sewage is already too dilute as a manure without making it still poorer by removing a portion of its fertilising ingredients. In some cases it may be found desirable to discharge town sewage into deep sea-water, simply because land for irrigation cannot be got, and the sea is close at hand. Under such circumstances a precipitation process might be found useful if a precipitant sufficiently inexpensive could be discovered. Where, however, land of suitable quality can be got, and its situation is favourable, the sewage should be directly applied to it without any previous chemical treatment.

CHAPTER XXXV.

ANIMAL MANURES.

Flesh and Blood. — The *flesh* of warm-blooded animals is a valuable manure—not, however, much used for manurial purposes. In some manure-manufactories the carcasses of horses are subjected to the action of steam, sulphuric acid, &c., reduced to pulp, and mixed with superphosphate of lime. The carcasses of animals that perish from disease should be cut up into pieces, and mixed with 4 times their bulk of a mixture of 3 parts of clay and 1 of quick-lime. The compost so formed will not prove a nuisance, but within a year, if kept under cover, will be converted into a valuable fertiliser. A carcass weighing 500 lb. yields about 12 lb. of ammonia, 24 lb. of bone phosphate, and 1 lb. of potash, besides a large amount of organic matter.

Blood.—It is a curious fact that there is nearly as large an amount of *dry* matters in blood as in very lean flesh. The latter contains about 74 per cent, the former from 78 to 82 per cent, of water. 100 parts of blood contain about 2½ parts of nitrogen, together with very small quantities of phosphoric acid and potash. Where pigs or other animals are killed upon a large scale (to make bacon, for example), large quantities of blood are available for manurial purposes. The blood is in these places often dried with or without the addition of sulphuric acid, gypsum, &c. The process is an offensive one, unless great care is taken

to prevent the escape of the noxious vapours, &c., evolved from the blood into the atmosphere. The blood is never thoroughly dried; but sometimes it is sufficiently desiccated to yield from 8 to 10 per cent of ammonia. We have, however, examined specimens of dried blood in which there was only present nitrogen equal to from 5.8 to 7 per cent of ammonia.

A rich compost is made by mixing blood with its own weight of wood or peat ashes, to which a little charcoal is a useful addition. This compost requires about a year to become matured.

Blood is about equal to flesh as a manure, the larger proportion of water which it contains being compensated by its greater facility for mixing with other substances, and with the soil, and its tendency to decompose more rapidly. Its effects are, it is said, more marked in light lands than in stiff clays.

Hides, Horns, Hoofs, Hair, and Feathers are identical in composition. When dry they contain from 16 to 17 per cent of nitrogen, but nothing else of any importance. Whalebone resembles horns. The large amount of nitrogen in these substances renders them valuable to the manure-manufacturer, who often finds it difficult to procure cheap ammonia-producing materials. It is, however, only the hoofs of cattle, the refuse part of hides in the process of tanning, the parings of leather, dust, &c., from the comb-maker, and similar refuse matters, which the manufacturer purchases. In these there is always a large admixture of sand, lime, and other useless matters, and the amount of nitrogen in them varies from 4 to 8 per cent.

Horns and similar substances remain for years un-

decomposed in the soil, and therefore they are of little value if means be not adopted to hasten their decomposition. Made into composts, it requires several years before they are converted into soluble manures. In the chemical manure works, they are covered with sulphuric acid, which in the course of some months renders them in great part soluble. The stronger the acid is, the more readily does it act upon the texture of the horns, &c.; and if the acid be hot, so much the better. Instead of mixing dissolved leather-clippings, &c., with superphosphate of lime, it is better to put them together with the raw phosphate into the mixer (page 343), and pour the acid down upon both. The free acid in the mixture of leather-clippings, &c., will then prove serviceable in *vitriolising* a portion of the phosphate.

Tallow-greaves (the nitrogenous residue after melting tallow) are chiefly used in making prussiate of potash, but occasionally they are used as manure. They resemble hair in composition, but decompose more readily.

Animal guano is the term applied to a manure now largely manufactured in the United States from the refuse parts of animals. Being in great part composed of substances which decompose very slowly, its effects as a manure will hardly correspond to the high money value which its chemical composition has induced its importers to place upon it. It is very variable in composition, some specimens being rich in phosphates, others in nitrogen; the former are for obvious reasons to be preferred. This manure seems better adapted to meet the wants of the manure-manufacturer than those of the farmer. It contains

from 3.5 to 5 per cent of nitrogen, and from 35 to 45 per cent of phosphates.

Wool, when dried and deprived of its fatty ingredients, contains as much nitrogen as hair, feathers, &c. Some varieties contain, however, very large proportions of a peculiar fatty matter termed *suint*, which is rich in potash. Raw merino wool contains from one-fourth to one-third of its weight of suint. In France the removal of potash from wool constitutes a small industry. 1000 lb. of raw merino wool yield from 70 to 90 lb. of potassic carbonate, and from 5 to 6 lb. of potassic chloride and sulphate. In the wool of British sheep there is about 10 per cent of potash-salts, so that these animals withdraw a considerable amount of potash from the lands which maintain them.

Woollen rags and *shoddy* (the latter a waste material from the cloth-mills) are largely used as manures. In Kent, woollen rags are applied in a compost form to the hop-plants, and are so much esteemed for that purpose that £5 per ton has been paid for them by the hop-growers. Shoddy seldom commands more than £2 per ton, as it often contains only 4 per cent of nitrogen, whilst woollen rags sometimes include 8 per cent. Woollen rags and shoddy can be rendered more immediately available as a manure by digesting them for some months with oil of vitriol.

Fish.—The refuse of the pilchard and herring fisheries, and the whole fishes, together with mackerel, sprats, &c., when captured in numbers too great to find a market, are occasionally used as manure. They should be applied in the form of a compost, which may consist of 5 barrels of fish (or fish-refuse), and 3 times as much clay, peat-mould, &c., per acre.

dition to the moist fibre of the plant itself. When once it has been dried, the vegetable matter of the sap loses this easy tendency to decay, and thus admits of longer preservation.

The same rapid decay of green vegetable matter takes place when it is buried in the soil. Hence the cleanings and scourings of the ditches and hedge-sides form a compost of mixed earth and fresh vegetable matter, which soon becomes capable of enriching the ground. When a green crop is ploughed into a field, the whole of its surface is converted into such a compost — the vegetable matter in a short time decays into a light, black mould, and enriches in a remarkable degree the soil. This is one reason why the success of wheat after clover, or of oats after lea, depends so much on the ground being well covered when first ploughed up.

The practice of green manuring has been in use from very early periods. The second or third crop of *lucerne* was ploughed in by the ancient Romans—as it still is by the modern Italians. In Tuscany, the *white lupin* is ploughed in—in parts of France, the bean and the vetch—in Germany, *borage*—and upon sandy soils in Holstein, *spurry*. In parts of Northern France, two crops of *clover* are cut, and the third is ploughed in. In some parts of the United States the clover is never cut, but is ploughed in as the only manure; in other districts the first crop is cut and the second ploughed in. In some of the northern States, Indian corn is sown upon poor lands, at the rate of 4 to 6 bushels an acre; and two or sometimes three such crops are put into the soil during the summer.

In Sussex, and in parts of Scotland, *turnip*-seed has been sown at the end of harvest, and after two months again ploughed in, with great benefit to the land. *Wild mustard,* also, which grows so abundantly as a weed on many of our corn-fields, is not unfrequently raised for ploughing in green. White mustard is sown in Norfolk, and ploughed in as a preparation for wheat; sometimes, also, on the stubble, as a preparation for turnips. It is said to destroy the wire-worm. *Turnip-leaves* and *potato-tops* decay more readily and more perfectly, and are more enriching, when buried in the green state. It is a prudent economy, therefore, where circumstances admit of it, to bury the potato-tops on the spot from which the potatoes are raised. Since the time of the Romans, it has been the custom to bury the cuttings of the vine-stocks at the roots of the vines themselves; and many vineyards flourish for a succession of years without any other manuring. In the Weald of Kent the prunings of the hop-vine, chopped and dug in, or made into a compost and applied to the roots of the hop, give a larger crop, and with half the manure, than when they are burned or thrown away, as is usually done.

Buckwheat, rye, winter tares, clover, and rape, are all occasionally sown in this country for the purpose of being ploughed in. This should be done *when the flower has just begun to open*, and, if possible, at a season when the warmth of the air and the dryness of the soil are such as to facilitate decomposition.

That the soil should be richer in vegetable matter after this burial of a crop than it was before the seed of that crop was sown, and should also be otherwise

benefited, will be understood by recollecting that perhaps three-fourths of the whole organic matter we bury has been derived from the air—that by this process of ploughing in, the vegetable matter is more equably diffused through the whole soil than it could ever be by any merely mechanical means—and that by the natural decay of this vegetable matter, ammonia and nitric acid are, to a greater extent, produced in the soil, and its agricultural capabilities in consequence materially increased. Indeed, *a green crop ploughed in is believed, by some practical men, to enrich the soil as much as the droppings of cattle from a quantity of green food three times as great.* It is said that clover takes from the soil more potash, phosphoric acid, lime, and other mineral matters, than any other crop usually grown in England. But during its growth a large amount of nitrogenous matter accumulates in the soil, and this on its decay is transformed into nitrates, which are especially beneficial to cereals.

These considerations, while they explain the effect and illustrate the value of green manuring, show that he overlooks an important natural means of wealth who neglects to utilise the green sods and the crops of weeds that flourish by his hedgerows and ditches. Left to themselves, they will ripen their seeds, and sow them annually in his field; collected in compost-heaps, they will materially add to the weight of his crops.

Sea-weed. — Among green manures, the use of fresh sea-ware deserves especial mention, from the remarkably fertilising properties it is known to possess, as well as from the great extent to which it is

employed on all our coasts. The agricultural produce of the Isle of Thanet, in Kent, is said to have been doubled or tripled by the use of this manure; the farms on the Lothian coasts let for 20s. or 30s. more rent per acre when they have a right of way to the sea, where the weed is thrown ashore; and in the Western Isles, sea-weed, shell-marl, and peat-ash, are the three great natural fertilisers, upon which the agriculture of this remote region depends. In Ireland, sea-weeds are a favourite manure for potatoes.

The common red tangle, which grows farther out at sea, is in some districts preferred as a manure to the other varieties of sea-weed, when applied green or made into compost. At Oban, on the west coast of Scotland, the fishermen bring it in their boats and sell it on the shore at a shilling a cart. One cart is there reckoned equal to two of farmyard dung for raising potatoes. Used alone for this crop, it gives a good return, but generally of inferior quality. The potatoes are said to be of better quality when the sea-weed is put into the soil and covered with a layer of earth, upon which the potatoes are to be planted. On the south-east coast of Fife, where the sea-weed is laid on the stubble at the rate of 20 carts an imperial acre, ploughed in, and the turnips afterwards raised with half dung, the *clover is said never to fail.*

Sea-weeds decompose with great ease when collected in heaps or spread upon the land. During their decay they yield ammonia and saline matters—the latter in large quantities.

Especially to this saline matter may be ascribed the beneficial influence of sea-weed on garden asparagus,

originally a seaside plant, and upon fruits like raspberries, which contain much alkaline matter.

The value of sea-weed as a manure may be understood from the fact that when dry it contains from 20 to 30 per cent of ash, and about 2½ per cent of nitrogen. In its recent state it contains from 70 to 80 per cent of water.

Straw.—Almost every one knows that the sawdust of most common woods decays very slowly — so slowly, that it is rare to meet with a practical farmer who considers it worth the trouble to mix sawdust with his composts. This property of slow decay is possessed in a certain degree by all *dry* vegetable matter. Heaps of dry straw when alone, or even when mixed with earth, will ferment with comparative difficulty, and with great slowness. It is necessary, therefore, to mix it, as is usually done, with some substance that ferments more readily, and which will impart its own fermenting state to the straw. Animal matters of any kind, such as the urine and droppings of cattle, are of this character; and it is by admixture with these that the straw which is trodden down in the farmyard is made to undergo a more or less rapid fermentation.

The object of this fermentation is twofold: first, to reduce the particles of the straw to such a minute state of division that they may admit of being diffused throughout the soil; and second, that the dry vegetable matter may be so changed by exposure to the air and other agencies, as to be fitted to yield without difficulty food to the roots of the plants it is intended to nourish.

Straw is undoubtedly more valuable as a food than

as a manure, as we shall see when we come to treat of the feeding of the animals of the farm. The riper the straw is, the less valuable is it either as a manure or a food. In good wheat-straw, cut when not over-ripe, there is about 0.5 per cent of nitrogen, and 4 per cent of ash, including 0.5 per cent of potash, and 0.5 per cent of tricalcic phosphate. In oat-straw cut whilst somewhat green, there are somewhat larger quantities of nitrogen, potash, and phosphates. Barley-straw yields about 0.7 per cent of nitrogen, 0.8 per cent of potash, and 0.3 per cent of phosphates. Pea-straw contains from 1 to 1.5 per cent of nitrogen, 0.5 per cent of potash, and 0.75 per cent of phosphates.

Straw is best applied in a partially decomposed state to light soils, but in stiff clays it produces an excellent mechanical effect when put in fresh, or nearly fresh.

Sawdust applied largely to the land, has been found to improve it,—little at first, more during the second year after it was applied, still more during the third, and most of all in the fourth season after it was mixed with the soil. That any dry vegetable matter, therefore, does not produce an immediate effect, ought not to induce the practical farmer to despise the application to his land—either alone or in the form of a compost—of everything of the kind he can readily obtain. If his fields are not already very rich in vegetable matter, both he and they will be ultimately benefited by such additions to the soil.

Saturated with ammoniacal liquor, or with liquid manure, sawdust has been profitably used, and without further addition, in the raising of turnips. It may also be charred, either by burning or by alternate

layers of quicklime, and thus beneficially applied. It cannot, however, be regarded as other than a very poor manure.

Bran.—The bran and pollard of wheat are useful manures. Drilled in with the turnip-seed at the rate of 5 or 6 cwt. an acre, at a cost of £1, 2s. 6d., it brought the young plants rapidly forward, and gave one-third more in weight of bulbs than the other parts of the field, which had been treated in the same way in every respect, except that no addition of bran had been made to them. If moistened with urine and slightly fermented, the action of bran would no doubt be hastened and rendered more powerful; but it seems foolish to use so good a food as bran is for manurial purposes.

The husk of the oat, hitherto wasted at many of the oatmeal-mills, ought to be fermented and employed as a manure.

Brewers' Grains, though usually given as food to fattening cattle or to milch-cows, are by some of the farmers in Norfolk employed as a manure. They are supposed to pay best when mixed with farmyard manure.

Malt-dust, or Combings.—Used in the dry state, malt-dust decomposes slowly, and, from its extreme lightness, is applied with difficulty as a top-dressing. If it be moistened with liquid manure and laid in heaps for a few days till it heat and begin to ferment, it may be used either as a top-dressing for grass, clover, and young corn, or it may be drilled in with the seed. In this state it is employed without any other manure for the turnip or potato crop; but the turnip-seed should not be brought into immediate

contact with it in the drills. As it is poor in phosphates, it does not seem a proper sole manure for turnips.

Rape-cake.—It is from the straw of the corn-bearing plants, or from the stems and leaves of the grasses, that the largest portion of the strictly vegetable manures applied to the soil is generally obtained. But the seeds of all plants are much more enriching than the substance of their leaves and stems. These seeds, however, are in general too valuable for food to admit of their application as a manure. Still the refuse of some—as that of different kinds of rape-seed after the oil is expressed, and which is unpalatable to cattle—is applied with great benefit to the land. Drilled in with the winter or spring wheat, or scattered as a top-dressing in spring at the rate of 5 cwt. an acre, it gives a largely-increased and remunerating return.

In some districts it is used largely, and without admixture, for the raising of turnips. It is applied with equal success in the cultivation of potatoes, if it be put in the place of a part only of the manure. If used alone it is apt to give very large and luxuriant tops, with only an inferior weight of tubers. It is safer, therefore, to mix it with other manure; and generally it may be substituted for it at the rate of about 1 cwt. of rape-dust for each ton of farmyard manure. Rape-cake contains from 4 to 5 per cent of nitrogen, and about 6 per cent of ash, chiefly composed of potassic phosphate.

During recent years rape-cake is, and properly, used as a food for cattle.

Oilcake Refuse.—*Hemp*, *poppy*, and *cotton cakes*—the refuse of crushed hemp, poppy, or cotton seed—

may be used for similar purposes, and in the same way, as rape-cake. *Cocoa-nut cake*, left by the expressed cocoa-nut, is also a valuable manure, and has alone been found to produce large crops of potatoes.

These different kinds of cake all contain from 3.5 to 4.5 per cent of nitrogen. They ferment very easily, promote growth rapidly, and give to the manures that contain them peculiar fertilising virtues. They are now, however, chiefly used as food for stock.

Peat. — In many parts of the world, vegetable matter continually accumulates in the form of peat. This peat ought to supply an inexhaustible store of organic matter for the amelioration of the adjacent soils. We know that by draining off the sour and unwholesome water, and afterwards applying lime and clay, the surface of peat-bogs may be gradually converted into rich corn-bearing lands. It must therefore be possible to convert peat itself by a similar process into a compost fitted to improve the condition of other soils. Partially dried, it may be very beneficially employed in absorbing the liquid manure of the farmyard, or in mixing with the contents of the tanks.

Peat-compost. — Many other ways of working up peat have been suggested, such as adding lime, salt, and other substances, to aid the fermentation. Mr Fleming of Barochan prepared a peat-compost consisting of—

Sawdust, or dry earthy peat, ...	40 bushels.
Coal-tar (ammoniacal liquor from gas-works?)	20 gallons.
Bone-dust, ...	7 bushels.
Sulphate of sodium, ...	1 cwt.
Sulphate of magnesium, ...	1½ ,,
Common salt, ...	1½ ,,
Quicklime, ...	20 bushels.

These materials were mixed together and put into a heap, and allowed to heat and ferment for three weeks, then turned, and allowed again to ferment, when the compost was ready for use.

Charred Peat.—By being built up and charred or half burned in covered heaps, peat may be obtained in a state in which it is easily reduced to powder. In this powdery state it has been used alone for turnips, at the rate of 50 bushels an acre, and was found to give as good a crop as 50 carts of farmyard dung—which is rather singular, as the composition of charred peat does not indicate a high manurial power. Charred peat forms an excellent absorbent for the liquids of the farmyard and the stable, and for drying up dissolved bones.

Tanners' Bark is a form of vegetable matter which, like sawdust and peat, is difficult to work up, and is therefore often permitted largely to go to waste. Like peat it may be dried and burned for the ash, which is light, portable, and forms a tolerably good top-dressing. It is best used in compost form. The hard thick fragments of bark, however, cannot be so soon decomposed as the already finely-divided peat, and must be expected, therefore, to demand more time. With lime it may, like sawdust or peat, be decomposed.

Charcoal and Soot.—When wood and other vegetable substances are heated in close vessels they are converted into charcoal. Coal (which is of vegetable origin), deposits in our chimneys, when burned, large quantities of soot; and when distilled in gas-retorts it yields, besides gas, a quantity of coal-tar and other products. All these substances have been tried and recommended as manures.

Charcoal-powder possesses the remarkable properties of absorbing noxious vapours from the air and from the soil, and of extracting unpleasant impurities as well as saline substances from water, and of decomposing many saline compounds. It also absorbs into its pores much oxygen and other gases from the air. Owing to these and other properties, it forms a valuable mixture with liquid manure, nightsoil, farmyard manure, ammoniacal liquor, or other rich applications to the soil. It is even capable itself of yielding *slow* supplies of nourishment to living plants; and it is said to be used with advantage as a top-dressing. In moist charcoal the seeds sprout with remarkable quickness and certainty; but after they have sprouted, they do not continue to grow well in charcoal alone. Drilled in with the seed, charcoal-powder is said greatly to promote the growth of wheat. Placed round the roots of the dahlia, it darkens and enriches the colour of the flowers. It acts in the same way upon roses, petunias, &c., when spread over the soil.

Charcoal prepared from sea-weeds is recommended by Mr Stanford as a valuable vehicle for applying animal manures to the soil.

Soot, whether from the burning of wood or of coal, consists chiefly of a finely-divided charcoal, possessing the properties above mentioned. It contains, however, ammonia, gypsum, nitric acid, and certain other substances, to which its well-known effects upon vegetation are chiefly to be ascribed. In many localities it increases the growth of the grass in a remarkable degree; and as a top-dressing to wheat and oats, it sometimes produces effects equal to those which follow the use of sodic nitrate.

Thus wheat and oats dressed with soot, in comparison with undressed, gave the following return of grain :—

	Wheat.	Oats.
Undressed, ...	44 bushels.	49 bushels.
Dressed, ...	54 ,,	55 ,,
	—	—
Increase,	10 ,,	6 ,,

It acts also upon root crops—56 bushels of soot mixed with 6 of common salt having produced larger crops of carrots than 24 tons of farmyard manure, with 24 bushels of bones.*

Soot contains from 16 to 40 per cent of mineral matter, consisting of earthy substances from the coal carried up into the chimney by the draught, and of gypsum and magnesic sulphate derived from the lime of the flue and the sulphur of the coal. It contains, besides, from 1 to 4 per cent of ammonia, chiefly in the state of sulphate.

When applied to grass in spring, it is said to give a peculiar bitterness to the pasture, and even to impart a disagreeable flavour to the milk. Hence, in large towns, the cowfeeders of the milk-dairies are sometimes unwilling to purchase early grass which has been manured with soot.

Coal-dust.—In the county of Durham the dust of common coal, such as is sifted out at the mines as too small for burning, has been spread upon poor, cold, arable land, and as a top-dressing upon old pastures, with, it is said, advantage. Something will, no doubt, depend both upon the quality of the coal and upon the kind of land to which it is applied, but it seems a very poor manure.

* Journal of the Royal Agricultural Society of England, iv. 270.

Leaves of trees, if abundant, should be collected and used as litter. They may also be ploughed in, fermented or not according as the soil is light or stiff. They vary considerably in composition, but generally contain from 6 to 10 lb. of nitrogen, 1 to 3 lb. of potash, and 1 to 4 lb. of phosphoric acid per 1000 lb.

Wild Plants.—Some weeds and other wild plants contain large quantities of nitrogen and ash, whilst others are poor in these constituents. Thus Anderson found in nettles, 0.34 per cent of nitrogen in the stems, and 0.92 per cent in the leaves. The ash of the former amounted to 1.66, and of the latter to 4.34; the ash was rich in potash-salts, but not in phosphoric acid. The buttercup and coltsfoot contained 0.21 and 0.31 per cent of nitrogen respectively, and each yielded a little over 2 per cent of ash, rich in potash, but poor in phosphoric acid.

If, as asserted, sedges, rushes, and ferns contain from 15 to 27 lb. of potash per 1000 lb., they might be used as a commercial source of that substance; at least they ought to be collected and applied as manures.

CHAPTER XXXVII.

SALINE AND EARTHY MANURES.

The general nature and mode of operation of such saline and mineral substances as are capable of acting as manures, will be understood from what has already

been stated as to the necessity of nitrogen and of inorganic food to plants, and as to the kind of inorganic food which they especially require. It will be necessary, however, to explain here more fully the composition of some of the substances which supply crops with these substances.

Ammonia-salts. — The value of ammonia as a manure has been already referred to (pages 41-43). It exists in all fermenting animal manures, and thus is constantly applied to the land even in districts where least attention is bestowed upon the cultivation of the land. According to Thaer, 8 lb. of ammonia per acre is the maximal quantity required during a four-course rotation.

Ammonia, or Gas-liquor.—Coal contains from 1 to 2 per cent of nitrogen. In the process of making coal-gas, this nitrogen combines in great part with a portion of the hydrogen of the coal, and forms ammonia-gas (NH_3). In purifying the coal-gas a large proportion of the ammonia which it contains is condensed, and, together with carbonic, acetic, prussic, and other acids, sulphuretted hydrogen, tarry matters, &c., constitutes what is termed *gas*, or *ammonia-liquor*. One ton of coal generally yields about 10 gallons of ammonia-liquor, containing from 3½ to 6 oz. of ammonia per gallon. From one ton of gas-liquor ½ cwt. of ammonia (equal to 2 cwt. of sulphate of ammonia) may at least be expected. To the farmer this would be worth about 30s., unless the cost of conveying it from the gas-works to the farm be considerable.

To grass-land this ammoniacal liquor may be applied with advantage by means of a water-cart—

being previously diluted with from three to five times its bulk of water. If too strong, it will burn up the grass at first, especially if the weather be dry; but, on the return of rain, the herbage will again spring up with increased luxuriance.

On arable land it may be applied to the young wheat or other corn by the water-cart, or it may be dried up by peat, charcoal, sawdust, or any other suitable porous material, and thus put into the turnip or potato drills. Added to liquid manure or to composts of any kind (under cover) it greatly enhances their value. Manuring with gas-liquor cannot, however, be expected to keep the land in heart. A certain proportion of bone-dust should be mixed with it, or else the corn crops should afterwards be top-dressed with guano, or bones. If, indeed, the land be already *bone-sick*, the saturated sawdust, &c., may be used alone, or with a mixture of wood or peat ashes for one rotation.

Gas-liquor is said to extirpate moss from old grass-land more permanently than lime.

Ammonic carbonate is the common smelling-salts of the shops. It exists in the ammoniacal liquor above described, and is very useful, in a diluted state, in promoting vegetation. Only it is too expensive, in the form in which it is at present sold, to be used as manure. An ounce of it, dissolved in a gallon of water, gives a solution which destroys insects on rose-trees and other plants, and adds to their luxuriance at the same time. A few pieces laid on a plate and allowed to evaporate slowly into the atmosphere of a conservatory, are said to add greatly to the green and healthy appearance of the plants.

Sulphate of Ammonia (*Ammonic Sulphate* = $(NH_4)_2SO_4$).—This salt when pure contains 25.75 per cent of ammonia (NH_3), but as sold for manurial purposes it contains only from 23 to 24.5 per cent. At a red heat it should be altogether dissipated, any residue being an impurity. This salt is obtained by distilling gas-liquor, and receiving the ammonia which is evolved therefrom into sulphuric acid. The solution of ammonic sulphate thus formed is evaporated in shallow pans until crystals begin to be formed.

Sulphate of ammonia is liable (but rarely) to contain a small quantity of ammonic sulphocyanide (NH_4CNS)—a salt which is highly poisonous to vegetation. If a solution of ferric chloride (Fe_2Cl_6)—which may be prepared by dissolving iron-rust in spirits of salt—causes a red colour to be produced when it is mixed with a strong solution of sulphate of ammonia in water, ammonic sulphocyanide is sure to be present.

This salt may be applied with advantage, especially to soils which are locally called *deaf*—which contain, that is, much inert vegetable matter—and to such as are naturally rich in phosphates. It may also be mixed with bones, rape-dust, or wood-ashes, and put into the turnip or potato drills; or it may be used as a top-dressing in spring to sickly crops of corn.

A case is mentioned of a field being manured for wheat, in part with ordinary farmyard manure, and in part with 1½ cwt. per imperial acre (cost, £1, 2s.) of sulphate of ammonia—when the produce of the former was 24, and of the latter 33, bushels per imperial acre. In other cases, also, it has been found

a profitable application, both to young corn and to meadow-hay.

Sal-ammoniac (*Ammonic Chloride* = NH_4Cl), in a crude form, is occasionally used as a manure. It contains 31.78 per cent of ammonia when pure, and is therefore a more powerful fertiliser than sulphate of ammonia. It is not likely that the chlorine which this salt contains is of any use to vegetation, and therefore it can only be regarded as a source of ammonia. The solution of the salt dissolves calcic phosphate, but only in very small quantity.

Action of Ammonia.—According to Th. Schloesing, three-fourths of the ammonia exposed to the leaves of tobacco plants were absorbed (*Comptes Rendus*, lxxviii. 1,700). Mayer, however, believes that but a small proportion of ammonia is under ordinary circumstances absorbed by the aerial parts of plants, owing to the small proportion of ammonia in the atmosphere. Southerly winds are richest in ammonia.

Ammoniacal salts appear to produce a powerful effect upon the cereals. Whilst mineral manures alone give but a slight increase in the weight of grain crops, their produce is largely augmented by the application of ammonia-salts, without any other manure being used. On the natural grasses their effects are very striking, but they do not produce so good an effect upon leguminous plants. Purely ammoniacal salts are not adapted for green crops; but they are a most valuable addition to the phosphatic manures which are usually applied to turnips, mangels, &c. Ammonia-salts are rarely applied except in combination with other substances, and then usually not in greater quantity than about one cwt.

per acre. It is more economical to use sulphate of ammonia in the spring, as when applied late in the year, much of it will be carried off in the drainage, especially if the soil be light and porous.

Steeping of seeds in the salts of ammonia.—The salts of ammonia, especially sal-ammoniac and the sulphate of ammonia, have been strongly recommended as steeps for seed-corn. They have in many cases been found very advantageous in hastening germination: thus, in one experiment, seeds of wheat, steeped in solution of sulphate of ammonia on the 5th of July, had by the 10th of August tillered into nine, ten, and eleven stems of nearly equal vigour; while unprepared seed had not tillered into more than two, three, or four stems.

Spent Iron Oxide.—In the purification of gas, a peculiar oxide of iron, termed *bog-iron ore*, is now largely used. It is chiefly ferric oxide (Fe_2O_3) mixed with peaty matter, and is found in large quantities in Ireland and elsewhere. It absorbs ammonia and sulphur from the gas, and, when saturated with these substances, is often sold to the chemical manure manufacturer. It often contains from 6 to 8 per cent of ammonia. It is a bad addition to superphosphate of lime, as it is certain to render a portion of its soluble phosphate insoluble. It has been used as a top-dressing for grass-land, some say with decided benefit, others asserting the contrary.

Lime from Gas-works.—This substance essentially consists of a mixture of calcic hydrate and carbonate (CaH_2O_2 and $CaCO_3$), together with 6 to 9 per cent of gypsum, and smaller quantities of other and unimportant matters. It contains mere traces of

ammonia. It is not a valuable manure, and is not worth its carriage, except for a very short distance. When fresh it contains sulphide of calcium, which is injurious to plants, but which by exposure to air becomes calcic sulphate. Gas-lime must not therefore be used until after some months' exposure to the air.

Nitrate of Soda (*Sodic Nitrate* = $NaNO_3$).—In all fertile soils nitric acid is certain to be found—chiefly as calcic nitrate ($Ca2NO_3$)—and often abundantly. It appears to be superior to even ammonia-salts as a source of nitrogen to most species of plants. Potassic nitrate (saltpetre) is found in immense quantity in India, but it is too dear to be used as a manure. Crude sodic nitrate (or cubic nitre) occurs in deposits of great extent in Peru, Chili, and Brazil. When purified from earthy matters, &c., it is exported—chiefly to Europe and the United States—to be employed in the manufacture of oil of vitriol, and to be applied as a manure. It is only valuable as a source of nitrogen. The nitrate of soda of commerce contains from 15 to 16 per cent of nitrogen, so that 2 parts of sulphate of ammonia contain about the same quantity of nitrogen as 3 parts of nitrate of soda.

Nitrate of soda may be applied to every kind of crop which requires nitrogen. Voelcker found that 1½ cwt. of nitrate of soda, costing £1, 2s. 6d., produced £4, 8s. 6d. worth of wheat grain and 12s. 6d. worth of straw; whilst 2 cwt. of sulphate of ammonia, costing £1, 12s., produced £4, 3s. 8d. worth of grain and straw to the value of 9s. 11d. Lawes and Gilbert found that nitrogen in the form of nitrate of soda produced heavier crops of barley than the same

weight of nitrogen did when applied as a constituent of ammonia-salts. In seasons of drought, soda nitrate is far more efficacious than ammonia-salts. Applied to root crops there does not appear to be any difference of importance between the effects of nitrate of soda and sulphate of ammonia. With clover and other leguminous crops the nitrate appears to produce extraordinary results (see page 306). It is an excellent top-dressing for meadow and pasture land, producing a rich green colour in the herbage and causing a luxuriant development of foliage. Nevertheless, it is desirable to combine phosphates with sodic nitrate in preparing a manure for meadow, or indeed any other, crops. In some cases, too, it should be combined with potash-salts and gypsum.

According to H. Fiedler, cubic nitre favours, even when used in small quantity, the absorption of phosphates, but it has but little effect on the absorption of potash.

Gypsum (*Calcic Sulphate* = $CaSO_4 + 2H_2O$) is applied to tracts of grass-land in Germany, and it is said with decided success. It supplies the lime and sulphuric acid which are annually removed by the crop. In the United States it is used for every kind of crop, and is alleged to produce very striking effects on Indian corn. It is specially adapted to the pea, the bean, and the clover crops. It is more sensibly efficacious when applied in the natural state than after it has been burned.

The *sulphates* all afford sulphur to the growing plant; while the lime, magnesia, potash, &c., which they contain, are themselves in part directly appropriated by it, and in part employed in preparing other

kinds of food, and in conveying them into the ascending sap.

Though there can be no question that these sulphates, and other similar substances, are really useful to vegetation, yet the intelligent reader will not be surprised to find, or to hear, that this or that mineral substance has not succeeded in benefiting the land in this or that district. If the builder has already bricks enough at hand, he needs mortar only to enable him to go on with his work: so, if the soil contain gypsum or sulphate of magnesium in sufficient natural abundance, it is at once a needless and a foolish waste to attempt to improve the land by adding more; it is still more foolish to conclude, because of their failure in one spot, that these same saline compounds are unlikely to reward the patient experimenter in other localities.

In Messrs Lawes and Gilbert's experiments on the growth of red clover (Jour. Royal Ag. Soc., vol. xxi. pt. 1), they found that the produce was considerably increased by the use of gypsum. During four years the average increase (as compared with unmanured plots) was nearly one ton of hay per acre.

According to A. Cossa, a saturated solution of gypsum dissolves from 0.0138 to 0.0714 per cent of matter from various rock materials, felspar (rich in potash) being the most soluble. He believes that gypsum increases the fertility of soils by decomposing the alkaline silicates, and liberating their potash and soda.

Those who largely use mineral superphosphates should recollect that nearly one-half of the weight of those manures consists of gypsum.

Magnesic Sulphate ($MgSO_4 + 7H_2O$) is occasionally introduced into *special* manures, prepared by manufacturers for corn crops. As magnesia is an abundant constituent of the seeds of the cereals, its salts may occasionally be found of use; but they are rarely purchased directly by the agriculturist. In most manures magnesic phosphate or carbonate occurs in small quantities, and there are few limestones from which magnesic carbonate is absent.

Potash-salts.—The salts of potassium used as manures are not so dear as they were a few years ago; and if they are really useful fertilisers, their cost is no longer an obstacle to their use. We have seen that potassium salts are indispensable to plants, and that they constitute a large, sometimes the larger, proportion of the weight of their ashes. In some soils potash exists even to the extent of 2 per cent; but in general it is present in the proportion of 0.1 to 0.4 per cent. In light sandy, and in calcareous, soils it is sparsely diffused. We have seen (page 284) that the crops imported from the farm carry off several pounds of potash per acre. Now the artificial manures already described furnish but trifling quantities—Peruvian guano, 1 per cent; superphosphates, a mere trace —to the soil, which therefore depends upon farmyard manure to make good the losses in potash which it sustains. As farmyard manure restores only a portion of the abstracted potash, it would seem reasonable that artificial manures should make up the deficit. The experiments which have been made with potash salts are not numerous; but so far as they go, their results appear to prove—1st, That potash-salts used alone do not produce a sensible increase in the pro-

duce of cereal crops; 2d, That they generally augment the produce of clover, potato, and, but in a minor degree, mangel crops; 3d, That they produce the best effect upon light lands; 4th, That they should always be used as an auxiliary, and not as a sole, manure. Hunter states (Transactions of the Highland and Agricultural Society for 1873, p. 168) that the quality of the potato and the weight of its crop are greatly promoted by the application of potash. The largest potato crops raised at Rothamstead were manured with 3½ cwt. superphosphate, 550 lb. sodium nitrate, 300 lb. sulphate of potassium, and 100 lb. each of sodium and magnesium sulphates.

Potassic Chloride (KCl) has, under the name of muriate of potash, been used as a manure for many years, but not extensively. It contains 52.35 per cent of potassium, which is equal to 63.1 per cent of dry potash (K_2O). It is obtained as a by-product in the manufacture of potassic chlorate, in the purification of nitre, and in other manufactures. It is also obtained from molasses, from sea-water from which common salt has been separated, from crude potash-salts, and from kelp. The potassic chloride sold as a manure is often very impure, and should not be purchased without a guarantee that it contains a fair amount of the real salt.

Kainit.—Saline deposits, rich in potassic salts, are found at Stassfurt, near Magdeburg, in Germany, and an article prepared from these deposits has for some years past been imported into these countries under the name of *kainit.* In the salt-beds of Stassfurt the following minerals occur: *kieserite,* composed of magnesic sulphate and chloride and water; *com-*

mon salt; carnallite, a compound of magnesic and potassic chlorides and water; *polykalite*, composed of calcic, magnesic, and potassic sulphates; *calcic sulphate; magnesic chloride;* and one or two other minerals. As crude potash-salts are found elsewhere in Germany, and as the potassic chloride is very unequably distributed throughout the salt-beds at Stassfurt and elsewhere, the composition of kainit is variable. Good specimens contain chloride and sulphate of potassium equal to about 14 per cent of potash. Nearly one-fourth of kainit consists of magnesic chloride and sulphate; the rest is made up chiefly of common salt.

Voelcker found that kainit applied to mangels grown on a soil containing 0.14 per cent of potash and soda produced from 2 tons 2 cwt. 84 lb. increase when 1 cwt. was used, and 8 tons 6 cwt. 36 lb. when 4 cwt. was employed. He found, however, that common salt was equally efficacious. The kainit used contained 24.03 per cent of potassic sulphate, and no other potassium salt; so that it was hardly a fair test as to the effect of potash, *versus* soda, salts on mangels. Besides. Nobbe, Schröder, and Erdmann have shown that potassium in the form of chloride produced well-developed plants (of buckwheat), whilst potassic sulphate produced very inferior ones.

Potassic Sulphate (K_2SO_4) is the chief potash-salt in kainit, but it is very rarely used *per se*, being very dear. It contains 54 per cent of potash (K_2O). Kainit should contain 25 per cent of this salt. Though potassic chloride has been found a better food than the sulphate for buckwheat, Ferguson

asserts the contrary to be the case with respect to potatoes.

Potassic Carbonate (K_2CO_3) is not suitable as a manure; and *Potassic Silicate*, though recommended as useful in strengthening the stems of the cereals, has been found useless for that purpose.

Soda-salts.—The results of very many experiments prove conclusively that soda-salts (unless, perhaps, in inappreciable quantities) are not essential to any kind of plants; two of them are, however, employed as manures.

Soda-ash is an impure mixture, consisting chiefly of oxide and carbonate of sodium. It is not suitable as a manure, but is a valuable application for the destruction of slugs, &c., in the soil.

Common Salt, or *Sodic Chloride* ($NaCl$), has long been used as a manure, especially for root crops. It is said to destroy small weeds, to be an insecticide, to strengthen the stems of corn plants, and to increase the produce of grain. Experiments with common salt have, however, given discordant results; for whilst some experimenters found it a most valuable manure, others state that it proved useless. In general, scientific agriculturists do not think much of its manurial value, whilst the majority of practical farmers are of a contrary opinion. Liebig denied strongly the utility of salt as a manure, whilst Mr Lawes pointed out that money spent on it might be better invested. Dr Voelcker made, with the assistance of a professor of agriculture, several experiments with salt. Speaking of its application to cereals, he says that it produced hardly any effect upon the grain, and slightly diminished the yield of straw

Applied to grass-land, it caused no increase in the produce, but restrained any tendency the plants might have had to become too luxuriant—*i.e.*, rank and coarse. Dr Voelcker thinks that salt might prove useful in preventing the foliage of green crops from becoming too highly developed at the expense of the roots. In his experiments with mangels he found, however, that both common salt and crude potash-salts added to the weight of the crops. Solution of common salt has the power of dissolving calcic phosphate and of liberating nitrogen from insoluble forms in farmyard manure, guano, &c. : in this way it may prove useful. On poor land salt will not produce an appreciable effect; but on soils where there is abundance of decomposing organic matter it will generally prove beneficial, but only in an indirect manner. Soda-salts are readily washed out of soils, and are generally to be met with abundantly in the drainage from heavily-manured fields.

The best kind of common salt is that which is procured from the fish or bacon curer, as it contains some animal matter, and is sold cheaply. Sometimes this waste salt is very wet, which detracts from its value.

Salt-cake, or *Sodic Sulphate* (Na_2SO_4), is often an ingredient in the grass and corn special manures prepared by the artificial-manure makers. Sodic sulphate, produced in the vitriol-works by decomposing sodic nitrate by sulphuric acid, generally contains a small quantity of nitrate of soda, which adds to its manurial value.

Lawes and Gilbert found that sodic sulphate largely increased the produce of red clover; but as the sulphates of calcium, magnesium, and potassium pro-

duced the same beneficial effect, it is probable that the sulphuric acid was the active agent in each case. Clovers require sulphur in large quantity. It is said that salt-cake has proved a good manure for potatoes.

Kelp.—Sea-weeds reduced to ashes constitute *kelp*. This substance is now chiefly used as a source of iodine and of potassium salts; but it is still occasionally employed as a manure, especially for potatoes. In Ireland it has been used for that purpose probably for a couple of centuries, and in the western and northern coasts of Scotland it has also been largely applied as a general manure. It is, however, bad economy to burn the weeds for the mere purpose of converting them into manure; by so doing, the large amount of nitrogen which they contain is lost. In the Channel Islands the sea-weeds (termed there *varec*) are burned as fuel, and their ashes carefully collected and used as manure.

Kelp is variable in composition, containing from 20 to 40 per cent of potassium salts, from 20 to 50 per cent of sodium compounds (chiefly as common salt and sodic carbonate), 3 to 8 per cent of calcic phosphate, and 15 to 40 per cent of earthy salts. "Drift-weed" contains less potash than "cut-weed."

Iron-salts.—Common copperas—ferrous sulphate ($FeSO_4 + 7H_2O$)—applied in the form of a weak solution to sickly, blanched plants, has been observed to change their colour to green, and to improve their appearance generally. It has been applied to diseased trees. Used in large quantity, it is poisonous to vegetation.

Ferric Phosphate is generally present in superphos-

phate of lime. When deposited in the soil it is usually precipitated — probably as $FePO_4 + 4H_2O$. In this hydrated and gelatinous state it is perhaps useful to crops.

Waste Lime Compounds. — The lime used by tanners and soap-makers, and the calcic sulphate from mineral-water manufactories, can generally be procured at nominal prices, and sometimes for the mere cost of carting. The first and last named are the most useful to the farmer; but they cannot be profitably conveyed to any but a short distance from where they are produced.

CHAPTER XXXVIII.

THE ADULTERATION AND VALUATION OF ARTIFICIAL MANURES.

Some years ago the practice of adulterating artificial manures, especially guano, was very prevalent; but lately, owing to repeated exposures, these valuable articles are sold in a purer state, though still occasionally sophisticated. When the farmer purchases guano, he should always either have it analysed at once, or a portion of it placed in a bottle, sealed, and kept locked up. If he subsequently find that the manure has not apparently produced any effect, he could then have the portion which he had preserved analysed; and if it were found to be

spurious, he could hold the person from whom he had bought the article responsible for the losses which he had sustained through its use. It is foolish to purchase artificial manures without knowing their composition, and having it guaranteed by the production of the results of their analyses.

Sometimes artificial manures are sold at prices much higher than their real money value, but on the faith of a statement showing their actual composition. If the farmer is unable to understand the analytical statement, a poor manure might appear to him to be a valuable one. For the benefit of farmers who are unable to judge of the value of a manure by means of the results of its analysis, chemists have long been in the habit of putting a money value upon the artificial manures which they examine. Thus the farmer who could not discriminate between the analyses of good and bad manures would know that one which was valued at £4 per ton by the chemist was not worth £6 or £7 per ton, which perhaps he had paid for it. There are difficulties in the way of valuing artificial manures. For example, it is usual to place from £90 to £100 per ton value on the ammonia which a manure yields, regardless of its source. Now, if the ammonia be derived from sulphate of ammonia, it will have cost the manufacturer twice as much as if he had used leather or wool waste as its source. Therefore, to both farmer and manufacturer, it is important that the source of the ammonia should be ascertained. The fee, however, which is usually paid for an analysis of artificial manure does not permit of a minute investigation into the sources of the substances present. The chemist determines the

amount of soluble and insoluble phosphates and the quantity of ammonia which the manure yields by complete decomposition, but he rarely carries the investigation further. When bones are used in making superphosphate, the soluble phosphate produced costs the manufacturer more than if he used coprolites or other mineral; but the chemist values the soluble phosphate in each case equally. However, in so doing he acts correctly, for there is no difference between the soluble phosphate produced from bones or guano and that obtained from mineral phosphates. The insoluble phosphate in manures which is derived from coprolites is, however, often incorrectly valued as if it were a constituent of bones or other organic material. This is manifestly an injustice to the maker of the bone superphosphates. The valuation of manures by the analyst is not approved of by the manufacturers, so far as the retail trade is concerned; yet they themselves invariably purchase their raw materials upon a similar basis—that is, so much per unit of ammonia and phosphoric acid present in a ton of the article.

At the present time farmers are able to purchase soluble phosphate at from £15 to £18 per ton; ammonia, as sulphate of ammonia, at from £90 to £100; bone phosphate—in bone-ash, at about £10 per ton, and in bones at £12 per ton; and sulphate of potassium, in kainit, at £14 per ton. In the wholesale manure trade, ammonia, phosphate of calcium, &c., are bought by what is termed the "unit"—that is, each per cent of the ingredient is multiplied by 20, and the product is said to be a unit of a ton, which manifestly it is not. The actual percentage of the

ammonia, &c., in the raw material is the proper factor by which to value the article.

Chemists generally value organic matter in manures at 10s. per ton, and gypsum and sodium salts at 30s. per ton respectively. They also usually value the nitrogen in the forms of nitric acid and ammonia equally. Most chemists value (to the retail buyer) soluble phosphate (*i.e.*, bone phosphate made soluble) at £16 to £20 per ton; insoluble phosphate, in bones, £10 to £12 per ton—in coprolites, £5 to nothing.

A simple way to calculate the money value of a manure is to make its constituents, as given in the analysis, represent 100 tons. The amount of each ingredient is multiplied by its price per ton, and all the products added together give the value of 100 tons. This result divided by 100 gives the value of one ton.

CHAPTER XXXIX.

FODDER CROPS.

More than one-half of the area of the United Kingdom is under meadows and permanent pastures. The plants which grow upon these lands belong to various orders, but chiefly to the *Graminaceæ* and *Leguminosæ*. They are used in three different ways: 1st, Animals eat them whilst they are growing; 2d, They are cut

and given in a green state to animals; 3d, They are cut and dried, in which state they form hay.

The Foliage and Stems of Green Crops contain much crude matter, and are not so nutritious as their composition seems to indicate.

COMPOSITION OF STEMS AND FOLIAGE OF GREEN CROPS.

	White Turnip.	Swedish Turnip.	Carrot.	Mangel.	Parsnip
Water, . . .	88.0	86.5	84.0	90.0	85.7
Albuminoids, .	2.5	3.2	3.2	2.0	2.0
Carbo-hydrates,	3.8	4.3	7.2	3.8	6.3
Fibre, . . .	3.9	4.2	3.1	2.6	2.6
Ash, ...	1.8	1.8	2.5	1.6	2.4

Straw.—The straws of cereals and some legumes constitute excellent food for cattle and horses. Their composition and nutritive value depend in a great measure upon the time at which they are cut. If allowed to grow until they are completely yellow, they lose much nitrogen, and their soluble albuminoids become in great part less soluble, and consequently less valuable. The greater part of the non-nitrogenous constituents of straws consists of cellulose, which when young and soft is digestible. Even the hard kinds of cellulose are partly digestible, as was shown by Stöckhardt and Sussdorf in their experiments on sheep. 100 lb. of good oat-straw, cut whilst somewhat green, usually contain 1¼ lb. of oil, 4 lb. of albuminoids, 10 lb. of sugar, gum, and other carbohydrates, and from 20 to 30 lb. of digestible cellulose.

In general the straws stand in the following order, the most nutritious being first: Pea, oat, bean with pods, barley, wheat, and bean without pods.

COMPOSITION OF STRAWS.

	Water.	Albuminoids.		Oil	Carbo-hydrates.	Fibre.		Ash.
		Soluble.	Insoluble.			Digestible.	Indigestible.	
*Irish oats, cut green, . .	14.00	4.08	2.09	1.84	13.79	59.96		4.24
* " over-ripe, . .	14.00	2.04	3.00	1.25	10.18	65.45		4.07
English oats, " . .	16.00	1.29	2.36	1.25	3.19	27.75	41.82	6.34
*Irish wheat, green, changing to yellow,	13.00	1.25	1.26	1.22	4.18	75.84		3.25
*Irish wheat, over-ripe, . .	12.14	0.44	1.41	1.14	3.88	77.76		3.23
Barley, not too ripe, . .	17.50	5.73		1.17	...	71.44		4.52
" dead ripe, . . .	15.20	0.68	3.75	1.30	2.24	5.97	66.54	3.24
Bean, ...	19.40	1.51	1.85	1.02	4.18	2.75	65.58	3.71
Pea, ...	16.02	3.96	5.90	2.34	8.32	17.74	42.79	4.95
Flax chaff, ...	14.60	47.75		2.82	8.72	18.56	43.12	7.37

* Those marked with an asterisk were analysed by C. A. Cameron, the rest by Dr Voelcker.

Why Hay Varies in Composition.—Owing to the great number of species of plants which make up the fodder crops, the different periods of their development at which they are consumed, the great varieties of soils on which they grow, the inconstant climatic conditions under which they are placed, and the differences in the composition of the manures applied to them, their composition is very variable. It is for these reasons that it is so difficult to compare the merits of the various fodder plants as articles of food.

The Composition of Plants changes during their Growth.—In the young plants, the proportions of water and mineral matters are high. Albuminous substances are abundant in the leaves, and as these constitute the greater portion of the young plant, nitrogen is abundant in it. As the stem increases, the proportion of nitrogen in the whole plant diminishes—the stem consisting mostly of cellulose, which contains no nitrogen. Fat is most abundant in the young plant, but the carbo-hydrates, especially cellulose, increase with the age of the plant. Clover increases in dry weight until the blossom is matured. Dr Voelcker determined the amount of soluble matter in clover at different stages of its growth. On the 2d of June the soluble matter constituted 40.04 per cent of the dry weight, and on the 28th July it fell to 29.27 per cent. E. Wolff found that red clover cut when young contained 21.9 per cent of albuminoids, but when the plants were old they included only 9.5 per cent. The ash under the same circumstances diminished from 9.8 to 5.6 per cent. Hellreigel and Stöckhardt's experiments in relation to this point confirm Wolff's results. Way found in young grasses 25.9 per cent of albuminoids, and in old ones only

Way determined the composition of the hay made from each of the more important artificial grasses. The mean results gave (the water in each case being taken at 16.6 per cent) 15.81 per cent of albuminoids, 3.18 per cent fats, 34.42 per cent non-nitrogenous digestible matters, 22.47 per cent woody fibre, 7.59 per cent ash. Yellow clover was the richest in albuminoids (20.50 per cent), corn-grass being almost equal to it (20.27 per cent). Rye-grass contained only 11.91 and millefoil 8.62 per cent albuminoids. The fat ranged from 3.98 per cent in cow-grass, and 3.89 per cent in hop trefoil, to 2.09 in millefoil.

According to Anderson, the second cutting of grass is equal in composition to the first.

Badly-made Hay. — Anderson found in inferior meadow-hay, one year old, only 4 per cent of albuminoids. It is true economy to cut hay early, and to get it off the field as soon as it is made. Voelcker has shown that hay quickly made is as valuable as the green plants from which it is produced; but that if it be too much exposed to the air, rain, and sun, or cut too early or too late, or allowed to heat in the rick, its quality becomes greatly deteriorated. Fermentation in the rick darkens the colour of the hay, causes a loss of sugar and of other soluble carbohydrates, and of soluble albuminoids. Acetic acid and aldehyde make their appearance, as does also (according to Hosaüs) ammonia. Experiments to test the feeding value of fermented hay showed that sheep lost weight when fed upon it.

Exhaustive Action of Hay Crops. — A crop of meadow-hay, weighing 2 tons, removes from the soil about 62 lb. of nitrogen, 70 lb. of potash, and 16 lb.

of phosphoric acid. From an acre, a crop of clover-hay, weighing 2½ tons, abstracts about 175 lb. of nitrogen, 110 lb. of potash, and 32 lb. of phosphoric acid; two or three of them grown in succession, and without manure, would put even good land out of *condition*.

Occasional Forage Crops.—The *Lentils*, the *Lupines*, the *Birdsfoot*, and the *Melilot* are occasionally grown as forage crops. They are leguminous plants, but, with the exception of the yellow lupine, are not much cultivated. That plant is grown extensively on the Continent, partly as a food, partly to furnish a green manure. It has been grown in England, but not to any extent. Mr Kimber states that cattle and sheep like it, but that pigs refuse to eat it. According to Voelcker, it resembles in composition the ordinary leguminous plants, save in one respect—remarkable deficiency in sugar. The best point in connection with the yellow lupine is that it may be profitably grown on very poor soils. *Rib-grass* (*Plantago lanceolata*) is often found in our meadows, but it is not a general favourite. *Green rye* is sometimes used as a forage crop, for which purpose many farmers consider it equal to clover. *Chicory* and *Buckwheat* have been employed as fodder crops, but chiefly on the Continent. Amongst the occasional forage plants may be mentioned the *Mustard*, the *Yarrow*, and the *Prickly Comfrey*. Mr Blundell recommends marrows and melons as excellent food for cattle in seasons of drought. He states that he has obtained more than 40 tons of them on a single acre. *Holcus saccharatus* was introduced into these countries a few years ago, but does not appear to have gained much ground as

a farm crop. It is rich in sugar, and is much relished by all the animals of the farm.

Rape is one of the best forage crops which we possess. Two varieties are commonly cultivated—Summer Rape (*Brassica campestris oleifera*) and Winter Rape (*B. rapus*). The importance of rape arises from the fact that it is generally grown as a *stolen* crop; for with respect to its composition, it is inferior to most of the fodder crops. Rape grows so rapidly, that if it be eaten off promptly it may at once be succeeded by barley or oats, with clover or grass seeds. In this way a rape crop may be gained without displacing another crop. It need hardly be added that when rape is grown as a stolen crop it must be disposed of early in its growth. It is sometimes ploughed in.

The Cabbage is an excellent food for cattle, and deserves to be cultivated as a field crop to a far greater extent than it is at present. The superior alimental qualities of this plant are shown in a prize report by Mr John M'Laren of Inchture, in the 'Transactions of the Highland and Agricultural Society of Scotland for 1857.' He obtained 42 tons 14 cwt. of cabbages (value £18, 6s. 6d.) and 26 tons 12 cwt. of turnips (value £12, 6s. 7¼d.) per acre; and the profit made by converting these foods into mutton was greater in the case of the cabbages by the sum of £1, 15s. 11¾d.

The outer leaves of the cabbage are the most nutritious, and the young plants are superior to the old. As a fodder crop, the open-leaved varieties are to be preferred to the more compact kinds. The drawback to the use of the cabbage is that it cannot

be stored for any length of time, like the turnip or mangel.

The Furze (Gorse, or Whin) has in a few instances been regularly cultivated, and, as a wild plant, it is abundant on vast tracts of poor pastures. It belongs to the leguminous family, and three species are found in the British islands—namely, the Common Furze (*Ulex europæus*), the Dwarf Furze (*U. panus*), and the Upright, or Irish Furze (*U. strictus*). It flourishes on almost any kind of soil, and although benefited by moderate rain, it resists drought in a remarkable manner. The Rev. Mr Townsend of Aghada, county of Cork, states that he obtained 14 tons of furze per acre. The plant should be cut young. Horses like it, cattle do not refuse it, but it is said that sheep and pigs do not seem to relish it much.

The Comfrey.—The Common Comfrey (*Symphytum officinale*) and the Prickly Comfrey (*S. asperrimum*) are occasionally cultivated as forage crops; and attention has recently been called to the value of the latter as a crop yielding a large amount of excellent food. These plants require good soils. At first the produce yielded by them is not large; but after two or three years they give three or four cuttings of from 6 to 9 tons each per acre. The analysis of the Prickly Comfrey, given in page 408, was made many years ago by Sprengel. The plant requires re-examination. The nitrogen of leaves and roots in part exists in the form of amides, and therefore is incapable of forming albuminoids in animals. Mangels contain a large amount of amides—derivatives from ammonium salts.

Bran is used as food for horses, and for cattle also. Being rich in nitrogen, it is well adapted for the use of young animals; but it is apt to pass in part unchanged through their bodies. This disadvantage may to a great extent be obviated by cooking or fermenting it, or, but not so perfectly, by combining it with beans or other *binding* food.

Oats have a thick husk, which, unlike the thin skin of the wheat, is not rich in nitrogen; it is also poor in starch, but contains more cellulose and ash than the inner part (oatmeal). The chief albuminoid in oats is *oat-legumin*, or *avenin*. It resembles the legumin of peas, but is richer in sulphur.

Grandeau states that there is (contrary to the general opinion) no relation between the weight of oats and their nutritive value. He found that out of nineteen specimens of French-grown, and twenty-one of foreign-grown, oats, Irish black oats grown in 1874 were the most nutritious; yet they were much lighter than oats of very inferior composition. He recommends that omnibus companies and other large consumers of oats should have analyses made of them before determining the ration to be given to each animal.

The nutritive value of oatmeal is very high, and it has long been a staple food amongst the peasantry of Scotland. No food given to the horse exceeds oats in value, especially if the animal be hard-worked.

The quantity and quality of the grain of the oat yielded by the same soil are affected by the variety sown. This is shown by the following table of the results obtained by Mr Hay from eight different varieties of oats well known in Scotland, and grown under identical conditions:—

Variety.	Produce.		Meal yielded by 100 lb. of grain.
	Grain.	Straw.	
	bush.	cwt.	lb.
Potato oat,	69	62½	60⅓
Sheriff "	65¾	55½	52⅓
Berlie "	55½	55½	58
Hopetoun "	56½	56¾	60½
Blainslie "	52¼	60½	51¾
Sandy "	47	48½	60
Early Angus "	48¼	45¾	55⅔
Barbachla "	45	49	60½

Barley is a very valuable food for cattle. English and Irish barley appear to be somewhat superior to that grown in Scotland, whilst Irish and Scotch oats are superior to English oats.

Malted barley is made by moistening the grains for about forty-eight hours, and allowing them to germinate on a floor (occasionally turning them) until the plumule, or elementary stem, attains a length equal to about two-thirds of that of the grain; whilst a root (radicle) shoots out to a much greater length. The malt is then dried at a temperature sufficiently high to kill the immature plant, and the radicles and plumules (*malt-dust*) are separated from it by screening. The chief change which takes place during malting is the conversion of about one-eighth part of the starch of the grain into sugar: probably nearly as much starch is converted into soluble compounds—*dextrin*, *maltose*, &c. From 3 to 6 per cent of the weight of grain is lost in the process of malting, exclusive of the amount eliminated in the form of *dust*, or *combings*, which is about 3 or 4 per cent.

Many stock-feeders have a high opinion of the

nutritive properties of malt, and consider it to be worth more than its equivalent of barley. They consider that it is not only highly digestible itself, but that it promotes the assimilation of other and less digestible foods. Mr Lawes, on the contrary, maintains that a given quantity of barley produces more meat than the amount of malt into which it is convertible does. He supports his opinion by adducing the results of experiments which he made, by giving barley and its equivalent in malt to two sets of animals, and noticing the increased weight of each lot. The result was altogether in favour of the barley; as was also that of an experiment made many years ago by Dr Thompson of Glasgow, which proved that cows fed on barley yielded more milk and butter than cows fed with an equal weight of malted corn.

Malt combings (or *dust*), being extremely rich in nitrogen and saline matters, are excellent food, especially for young stock. They are generally sold at from £3 to £4 per ton, for which they are good value.

Bere is a species of barley, which it resembles in its proportions of nitrogen and starch; but it contains three times as much indigestible woody fibre. It is an inferior grain.

Rye is not now much used in these countries; but it is a common food for both man and the lower animals on the Continent, especially the northern part of it. It is said to be an excellent food for milch cows. Judged by its composition, it appears to be somewhat inferior to oats and barley.

Maize (*Indian corn*) was used largely as food by the Irish peasantry during the famine year of 1847, adn for some years subsequently. It is now rarely

eaten by them, being decidedly inferior in flavour to oatmeal. For fattening cattle, and even for horses, it is one of the best foods at present in use. The chief point in the composition of maize is its high proportion of fats, which has been known to reach even 9 per cent, and is generally about 5 per cent. The Galatz round yellow grain we have found to be superior in composition to the flat yellow seed from America.

Rice is poorer in nitrogen than any of the commonly-employed food-grains. It contains but little fat or ash, and its importance lies in its large percentage (75 to 80) of starch. Unless purchased cheaply, it is not so economical a food as maize or oats. *Rice-dust* is rarely worth the high price which it appears so readily to command.

Millet is the seed of several species of *Panicum setaria*, and allied genera, cultivated chiefly in India and other hot countries, but found occasionally in southern and eastern Europe. The grain is small, but nutritious, and is much relished by cage-birds and poultry.

Durra is often called Indian millet, but it is in reality a species of *Sorghum*. It is, perhaps, the commonest food-grain of Africa, and is largely cultivated in India and other parts of Asia. It is occasionally imported into these countries as food for cattle and poultry. It does not make good bread; but is an excellent material for puddings. It is intermediate between wheat and rice. In the United States and in Germany durra has of late been grown; in the latter country with doubtful success.

Buckwheat.—A genus of the natural order *Polygoneæ*, cultivated largely in Russia, Central Asia, and

the United States; and, but to a less extent, in Germany, France, &c. The Germans call its grain *buchweizen* (from its resemblance to beech-nuts), and from this term its English name is derived. It is often used as human food; but generally as a supplementary, not a staple, article. It is said to be as good as barley for cattle; but in these countries it is usually given only to game and poultry. If given to cattle, it should previously be deprived of its hard, indigestible, shell-like husk.

Spelt, though resembling wheat, is regarded as a distinct species (*Triticum spelta*). It is very inferior in flavour, but not so much in composition, to wheat; but it may be grown upon inferior soils, which would not produce satisfactory crops of wheat. It is chiefly found in Switzerland. A variety of spelt (*T. monococcum*) is called *St Peter's corn;* it is a very inferior grain.

COMPOSITION PER 100 PARTS OF SEEDS OF CEREALS

(Deduced chiefly from Wolff's Averages and Cameron's Analyses).

	Water.	Albuminoids.	Fats.	Starch, &c.	Fibre.	Ash.
Wheat, . .	15.0	12.0	1.5	67.0	2.8	1.7
Spelt, . .	15.0	10.0	1.5	66.8	5.0	1.7
Barley, . .	16.0	9.5	2.5	63.2	6.3	2.5
Bere, . .	14.3	9.0	2.5	59 7	12.0	2.5
Oats, . .	14.0	11.5	6.0	56.5	9.0	3.0
Indian Corn, .	14.5	10.0	7.0	61.4	5.2	1.9
Millet, . .	14.0	14.0	3.0	58.5	8.0	2.5
Buckwheat, .	14 0	9.0	2.5	60.2	12 0	2.3
Rye (Irish), .	16.0	9.0	2.0	64.0	8.0	1.0
Rice, . .	14.0	5.3	1.0	76.7	2.5	0.7

COMPOSITION OF PARTS OF SEEDS.

	Wheat.		Maize-meal.	Oat-meal.	Irish oat-meal.	Oat chaff and hulls.	Rye chaff and hulls.	Barley chaff and hulls.	Maize chaff and hulls.	Lin-seed bolls.	Rye flour.
	Bran.	Flour.									
Water, . . .	13	12.6	9.00	8.7	9.26	14.3	14.3	14.3	14	7.50	14.0
Albuminoids, . .	12	11.8	10.00	12.7	16.18	4.0	3.5	3.0	3	24.44	11.0
Fat, . . .	2	1.2	4.98	7.5	8.00	1.5	1.2	1.5	1.1	...	1.6
Carbo-hydrates, .	50	74.1	71.40	62.0	57.53	28.2	28.2	38.7	39	34.00	72.0
Woody fibre, . .	15	0.7	3.40	7.6	6.99	34.0	46.3	30.0	40	30.73	1.5
Ash, . . .	5	0.7	1.22	1.5	2.04	18.0	7.5	13.0	4	3.30	1.6
	100	101.1	100.00	100.0	100.00	100.0	101.0	100.5	101.1	98.97	101.7

The analysis of oatmeal is by Du Jardin-Beaumetz and Hardy, and of Irish oatmeal and maize-meal by C. A. Cameron. Nearly all the other analyses are Wolff's averages. The published analyses of the bran, chaff, and hulls of grain are conflicting and unsatisfactory. The subject requires further investigation.

Refuse parts of Seeds.—*Wheat bran* is not a very nutritious food for horses and oxen; but it makes a good warm mash, especially for milch cows. It is laxative—less so when cooked. *Wheat pollard* is intermediate between flour and bran, and possesses the mean feeding qualities of the two. The husk and toppings of oats contain very large amounts of woody fibre, as do also barley husks and awns, especially the latter. These articles should always be cooked. Way found the enormous proportion of 12 per cent of ash in barley awns. The sweepings of mill-floors often contain so much dirt and sand as not to be worth the price paid for them.

Leguminous Seeds.—The seeds of the bean, pea, and other legumes differ from cereal grains in containing much larger amounts of albuminoids, and proportionately smaller percentages of starch and fats. Their chief nitrogenous substance is *legumin* (page 79). It resembles the *casein* of milk; but is much more insoluble and indigestible. It requires powerful digestive organs to enable a man to assimilate beans, peas, &c., especially when they are old. They are good food for working animals; but are apt to produce constipation if largely consumed. They should be combined with oats or bran. The manure produced by leguminous seeds is double in value that produced from an equal weight of cereal grains.

Seeds of the *bean*, *pea*, *lentil*, *tare*, and *vetch* closely resemble each other in composition.

Oil-seeds are so dear that they are rarely given to cattle. Linseeds contain about 34 per cent of oil (which replaces starch) and from 20 to 25 per cent of albuminoids. They have a bland, pleasant flavour, and are greedily eaten by cattle. Mr Horne gave equal money's worth of (1) linseed-cake, (2) linseed, and (3) wheat and barley, to three lots of bullocks. Those fed on the cake increased in weight by 637 lb.; those supplied with the grain 667 lb.; whilst the lot fed with oil-seeds increased 718 lb. The animals, of course, had other foods in equal quantities.

Linseed, being laxative, is a suitable adjunct to beans. A mixture of bruised linseed with chopped and steamed straw is a good substitute for hay, when the latter is scarce.

Rape-seed is not so palatable as linseed; but it is richer in oil. Palm-nut kernels contain nearly 50 per cent of oil; hemp-seed about 32 per cent; poppy-seed, 40 per cent; cocoa-nut, 64 per cent; cotton-seed, 20 per cent; and earth-nut, 50 per cent. Walnut-meal, used as a cattle food in France, we have lately found to contain 29 per cent of oil and 28.8 per cent of albuminoids.

Analyses of Seeds.—It is acknowledged that the usual methods of determining the proportion of cellulose in vegetable substances are not very accurate. W. Pillitz has recently devised an improved method of determining the amount of this ingredient, and it has been made use of in the following analyses of seeds:—

CENTESIMAL COMPOSITION OF (DRIED) SEEDS.

100 parts dried at 100° contain—	Wheat (Prince Albert's).	Browick's Wheat.	Spelt.	Rye.	Millet.	Barley.	Oats.	Maize.	Rice.	Buckwheat.
Cellulose,	3.07	4.76	3.38	4.22	4.28	8.88	18.98	4.82	.87	2.05
Starch,	73.51	70.17	71.60	65.60	69.20	62.65	53.62	72.27	85.41	77.64
Dextrin,	2.28	5.27	2.46	5.78	1.29	1.96	1.46	.83	1.27	...
Sugar,	1.56	1.07	1.23	2.17	.52	2.71	.37	1.59	trace	...
Extractive matter, undetermined,	4.54	.81	3.00	3.50	.52	1.73	1.66	1.65	.12	3.65
Fat,	2.03	1.79	2.72	2.52	4.79	3.08	4.92	5.03	.90	2.89
Albuminoids, insoluble,	10.89	12.93	10.77	10.60	16.22	14.28	12.13	9.95	10.01	7.40
Albuminoids, soluble,	.38	.96	2.63	3.87	1.36	2.05	2.69	2.16	.46	4.67
Ash, insoluble,	.69	.61	.60	.24	.64	1.23	2.73	.38	.45	.61
Ash, soluble,	1.05	1.63	1.61	1.50	1.18	1.45	1.44	1.32	.51	1.09

COMPOSITION OF OIL-SEEDS.

	Linseed.	Rape-seed.	Rape-seed.	Hemp-seed.	Cotton-seed
	(T. Anderson.)		(C. A. Cameron.)	(T. Anderson.)	
Water, . .	7.50	7.13	7.12	6.47	6.57
Oil, . .	34.00	36.81	41.33	31.84	31.24
Albuminoids,	24.44	20.50	18.00	22.60	31.86
Carbo-hydrates, } Fibre, .	30.73	18.73	23.26	32.72	14.12
		6.86	5.66		7.30
Ash, .	3.33	8.97	4.63	6.37	8.91
	100.00	100.00	100.00	100.00	100.00

COMPOSITION OF LEGUMINOUS SEEDS.

	Common Beans.	Foreign Beans.	Peas.	Lentils.	Winter Tares (foreign).	Vetches.
Water, . . .	13.0	14.5	14.0	13.0	15.5	12.93
Albuminoids, .	25.5	23.0	23.5	24.0	26.5	27.50
Carbo-hydrates,	48.5	48.7	50.0	50.5	47.5	47.80
Fibre, . . .	10.0	10.0	10.0	10.0	9.0	7.17
Ash, ...	3.0	3.8	2.5	2.5	1.5	4.00
	100.0	100.0	100.0	100.0	100.0	100.00

The amount of fat in leguminous seeds is only 1 or 2 per cent, except in the lupines, in which it constitutes about 5 per cent.

Over-ripe Grain.—So soon as the upper portion of the straw becomes yellow, no further increase takes place in the weight of the seed. If the grain be not reaped soon after the appearance of this sign, its quality deteriorates, and its weight diminishes.

Grain, which is sweet and milky a month before it is ripe, gradually consolidates—the sugar changing into starch, and the milk thickening into the gluten and albumin of the flour. As soon as this change is nearly completed, or about a fortnight before it is ripe, the grain of wheat contains the largest proportions of starch and gluten. If reaped at this time, the

bushel will weigh most, and will yield the largest quantity of fine flour and the least bran.

At this period the grain has a thin skin, and hence the small quantity of bran. But if the crop be still left uncut, the next natural step in the ripening process is to cover the grain with a better protection—a thicker skin. A portion of the starch of the grain is changed into woody fibre—precisely as in the ripening of hay, of the soft shoots of the dog-rose, and of the roots of the common radish. By this change, therefore, the quantity of starch is lessened and the weight of husk increased; hence the diminished yield of flour, and the increased produce of bran.

Theory and experience, therefore, indicate about a fortnight before it is fully ripe as the most proper time for cutting *wheat.* The skin is then thinner and whiter, the grain fuller, the bushel heavier, the yield of flour greater, its colour fairer, and the quantity of bran less; while, at the same time, the straw is heavier, and contains more soluble matter than when it is left uncut until it is considered to be fully ripe.

In regard to *oats*, it is said that the superiority of Ayrshire oatmeal is partly owing to the grain being cut rather *glazy*—that is, with a shade of green upon it; and the straw is confessedly less nourishing for cattle when the crop is allowed to stand till it is dead ripe. Early-cut oats, also, are heavier per bushel, fairer to the eye, and usually sell for more money. A week before full ripeness, however, is the utmost that is recommended in the case of oats, the distance of the top and bottom grains upon the stalk preventing the whole from becoming so uniformly ripe as in the ear of wheat.

Barley cut in the *striped* state is also thinner in the skin, sprouts quicker and more vigorously, and is therefore preferred by the maltsters. It is also fairer to the eye, and generally brings a higher price in the market.

CHAPTER XLI.

OILCAKES AND OTHER "PURCHASED FOODS."

Oil-seeds are by hydraulic pressure deprived of about three-fourths of their oil. In a powerful press, and at a temperature of about 120° Fahr., they are exposed to pressure varying from 30 to 35 cwt. upon the square inch; the greater part of the oil flows out, and the residue is sold as linseed-cake, rape-cake, &c. The higher the temperature and the more powerful the pressure the less valuable is the cake.

Linseed-cake sells at (Feb. 1877) from £10, 10s. to £12 per ton. There are numerous varieties in the market, of which English and American are usually the best. That made from East Indian seed contains rape-seed, and is somewhat inferior to the European cakes. The oil varies in genuine cakes from 8.5 to 13, but is generally from 10 to 11.5, per cent. The albuminoids vary from 25 to 32, but on an average are about 26, per cent. The ash ranges from 5 to 9 per cent, but is usually 5.8 to 7 per cent. Linseed-cake is frequently adulterated with such substances as bran, rape-cake, flax, and straw. We have met with cocoa-nut meal in linseed-cake. It had

evidently been used to bring up the percentage of oil, which had been lowered by the addition of some non-fatty adulterant. Good linseed-cake has a reddish-brown colour, uniform appearance, and pleasant mild flavour and odour. Very dark cakes are generally over-heated, and very white ones adulterated. ¼ oz. mixed with an ounce of water should form a moderately stiff paste; if thin, bran or grass seeds are probably present, and may be seen through a low-power magnifying-glass. From 2 to 14 lb. of linseed-cake are given daily to bullocks, but a larger quantity than 7 lb. is wasteful. 2 to 3 lb. may be given to young animals according to age; ½ lb. per day is sufficient for a sheep. Horses do not eat it at first, but they soon acquire a taste for it. From 2 to 3 lb. per day are the allowances for a working horse. It is said not to be a good food for pigs, as it renders their flesh soft and oily.

Rape-cake sells at from £8 to £8, 15s. per ton. Judged by its chemical composition, it is equal to its weight of linseed-cake, but experience shows that it is decidedly inferior to the latter. This, no doubt, is owing to the acrid flavour which it possesses, and which is occasionally so intense that animals refuse the cake. The best rape-cake comes from Denmark and the north of Germany; it is yellowish-green.

The best way to use rape-cake is in a cooked state, and in combination with other and better-flavoured foods. Steaming it along with chopped straw is a good plan, but to this mixture a little molasses or bruised locust-beans should be added. It is not advisable to give more than 2 or 3 lb. of rape-cake per day to a bullock, unless the cake is unusually free from acrid matters, and is evidently relished by

the animal. Indian rape-cake is frequently (but accidentally) mixed with wild mustard or charlock seed, which renders it a somewhat unsafe food, unless used in very moderate quantities. If a portion of such a cake be powdered and heated with boiling water, the pungent odour of mustard will speedily be developed.

Cotton-seed Cake sells at present in the decorticated state at £9, 10s. per ton, and in the undecorticated condition at £7, 10s. per ton. At these prices it is the most economical cake which the farmer could purchase. Opinions differ as to the value of undecorticated (English) cotton-seed cake. Some stock-feeders allege that is a dangerous food, owing to the indigestible particles of cotton which it contains; whilst others assert that they have largely employed this food not only without injury, but, on the contrary, with good results. There are some undoubted cases of the death of sheep caused by accumulations of cotton in their stomachs. On the whole, we prefer the decorticated cake.

Palm-nut Meal is the residue from palm-nuts, from which the greater portion of their oil has been extracted. Its flavour is rank and oily; but its odour is not altogether disagreeable. The English meal is rich in fats; but the article which, under the name of palm-nut meal, is imported from the Continent, contains only from 7 to 10 per cent of fats, and is otherwise very inferior. Palm-nut meal is (after steeping for some hours in water) a suitable food for calves. It is a good ingredient for a mash for milch cows and pigs. A mixture of equal parts of palm-nut meal, cotton-seed cake, and Indian corn, is an excellent substitute for linseed-cake.

Cocoa-cake is prepared from the outer shell and a portion of the kernel of the cocoa-bean. It is an excellent food for all kinds of cattle.

Poppy, Nut-oil, and Dodder Cakes are poor in oil, and, unless used when fresh, are by no means good foods. They are often mixed with other cakes by oilcake manufacturers.

Locust or Carob Beans (pods of the carob tree or *Ceratonia siliqua*) contain merely a trace of oil, are not rich in albuminoids, but include a large proportion of sugar. They are not fitted for young animals, but are an excellent addition to food of indifferent flavour. It is difficult to grind them.

Molasses contains about 25 per cent of water, 50 per cent of crystalline sugar, 20 per cent of uncrystallisable sugar, and 5 per cent of saline matters. It does not form bone or muscle, being composed of carbo-hydrates only. It is valuable more as a flavouring ingredient than as a food. If used in large quantity it should be combined with beans or other highly nitrogenous food. It is alleged that if given in large quantity, molasses injuriously affects breeding animals. It is a laxative food.

Dates have been used as cattle food. They are poor in composition, containing only 2 per cent of nitrogenous matters, 2 per cent of saline substances, and 10 per cent of carbo-hydrates, chiefly sugar.

Distillery and Brewery Dregs are chiefly given to dairy cows. According to Anderson, 15 gallons of distillery wash equal 100 lb. of turnips. The wash so composed contained 4130 grains of organic matter per gallon (70,000 grains). Brewery dregs are sometimes kiln-dried and sold under the name of *desiccated* grains. They cannot be very digestible.

AVERAGE COMPOSITION OF OILCAKES, &C.

	Linseed-cake.	Rape-cake.	Palm-nut meal.	Cotton-seed cake		Cocoa-cake.	Poppy-seed cake.	Dodder-seed cake.	Locust-beans.
				Decorticated.	Undecorticated.				
Water,	7 to 10	10	18	1	12	14	12	12	14
Albuminoids,	22 ,, 30	30	16	35	22	20	32	30	7
Oil,	9 ,, 13	10	18	14	8	8	6	8	1
Carbo-hydrates,	30 ,, 36	32	37	24	32	31 }	38	42	68
Fibre,	8 ,, 10	10	16	9	20	20 }			7
Ash.	5 ,, 8	8	5	7	6	7	12	8	3

CHAPTER XLII.

ROOTS AND TUBERS.

Turnip Roots contain about 92 per cent of water. All the nitrogen in the solid portion of the turnip and other roots is not in the form of albuminoids, and their dry matter generally is in a lower degree of elaboration than the dry substance of seeds. The fat in roots has not been specially studied. Starch does not exist in turnips, but it has been found in carrots, and also, and in larger proportion, in parsnips. Sugar, pectose bodies, gum, and cellulose, make up the carbo-hydrates of roots. The Swedish turnip is the most valuable, and the greystone perhaps the most inferior, of turnips.

Mangel-wurzel Root contains a larger amount of solid (dry) matter than the turnip, and usually produces a heavier crop. When taken out of the ground its flavour is acrid; but when it is stored for some months it becomes far more palatable, owing, apparently, to the conversion of some of its insoluble carbo-hydrates into sugar. It is said that 75 lb. of mangels equal in nutritive power 100 lb. of turnips.

Parsnips are richer in dry matter than mangels, and they include a considerable amount of starch. Their nitrogenous constituents consist chiefly of casein —those of the turnip and mangel being principally albumin. Their food equivalent is about double that of the turnip. Parsnips are used as human food, but they are also occasionally given to pigs.

Beetroot is extensively produced in many Con-

tinental countries, and used as a substitute for cane-sugar; it is seldom cultivated in these countries, though an excellent food for cattle. It contains about double the quantity of dry matter found in turnips, and usually includes from 7 to 12 per cent of sugar.

The Carrot bears some resemblance to the parsnip, but is very much richer in sugar, and poorer in starch. It is deficient in nitrogenous matters, and is not, therefore, suitable for young animals; but it is greedily eaten by all kinds of farm animals.

Kohl-rabi, though allied to the turnip, differs widely from it in its mode of growth. Its bulb—an enormous expansion of its under-ground stem—is well-flavoured, contains as much nutritive matter as the best swedish turnips, stores well, and is not much liable to the ravages of insects. As it projects above the soil, it can be "eaten off" by sheep without being first *pulled*. Mr Baldwin of Glasnevin states, however, that he found Swedish turnips a more economical food for cattle.

The Radish contains 95 per cent of water, and is therefore but poor food. It might, however, under certain circumstances, be found a good *stolen* crop, as it can be grown within a month.

The Potato produces the best tubers used as food by man and the lower animals. Its acreable yield is usually good, and the composition of the tuber is greatly superior to that of any of the roots above described. We doubt, however, whether the potatoes grown since the great failure of the crop in 1847 and following years ever equal the "mealy" potato upon whose merits Cobbett expatiated so eloquently. The potato contains about 25 per cent of dry matter, of

which 2 per cent consists of albuminoids, 12 per cent of starch, and the rest fibre, ash, &c. It contains a mere trace of fat, and very little sugar. The defects of the potato as a staple food are its small proportions of fat * and albuminoids. Coarse kinds of potatoes are often given to oxen, horses, and pigs—especially the last-named animals. Patterson's *Bovinia* is a variety of the potato strongly recommended for cattle, its acreable produce being very large.

COMPOSITION OF SEVEN VARIETIES OF POTATO.

100 parts contain :—

	Champions.	Regents.	White Rock.	American.		Red-Skinned Flour-ball.	Belgians.
				Early Rose.	Goodrich.		
Water, .	72.50	79.87	77.42	77.38	77.08	76.11	72 03
Albuminoids,	2.28	1.52	1.62	1.58	1.69	1 90	2.11
Fats, . .	0.73	0.50	0.63	0.65	0 60	0.68	0.75
Carbo-hydrates, .	21.63	15.68	17.67	17.67	17.87	18.44	21.83
Cellulose, .	1.84	1.76	1.82	1.92	2 00	2 06	2.36
Ash, . .	1.02	0.67	0.84	0 80	0 76	0 81	0.92
	100 00	100.00	100.00	100.00	100.00	100.00	100.0

The Jerusalem Artichoke resembles the potato in being valuable only for its tubers. The plant may be grown on any soil save a very wet one, and it gives a good produce. The tuber contains about as much dry matter as that of the potato, but it includes very little starch, that substance being replaced by sugar. It keeps well, and is relished by most of the animals of the farm. It is largely used on the Continent, but is not much cultivated in these countries.

* On the average 0.73 per cent, of which about half exists in the peel.—EICHORN.

AVERAGE COMPOSITION OF ROOTS AND TUBERS.

	Swedes.	White Turnips.	Aberdeen Yellows.	Mangels.	Sugar Beet.	Carrots.	Parsnip.	Potato.	Jerusalem Artichoke.
Water,	89.46	92.00	90.56	88.00	83.50	87.50	85.00	75.55	80.0
Albuminoids,	1.45	1.08	1.40	1.40	1.30	1.20	1.36	2.06	2.0
Fat,	0.20	0.15	0.20	0.20	0.12	0.20	0.34	0.75	0.3
Sugar,	4.60	3.00	3.90	5.60	10.50	6.90	3.00	0.56	15.6
Carbo-hydrates,	2.55	2.21	1.90	2.91	2.30	2.07	7.90	17.98	
Insoluble cellulose,	1.12	0.96	1.04	1.13	1.24	1.10	1.40	2.12	1.3
Ash,	0.62	0.60	1.00	0.76	1.04	1.03	1.00	0.99	1.1
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.3

Over-grown Roots.—It is not advisable to force, by excessive manuring and thinning out, mangels and turnips to attain to "monstrous" proportions, as is so often the case. Over-grown roots contain an excessive proportion of water, are inferior in flavour, and do not keep; besides, an acre of monster roots generally yields less actual nutriment than an acre of moderate-sized ones of much less gross weight. This is well shown by the following experiment: *

Mangels and turnips were grown on the home farm of Mr W. Young, Brockley Park, Queen's County. Half of each crop was grown by itself, and the other moieties in alternate drills with each other. They were manured with 35 tons of dung, 3 cwt. of superphosphate of lime, 1 cwt. of nitrate of soda, and ½ cwt. of Peruvian guano per Irish acre. The drills were 28 inches apart, except one small crop of mangels, which were thinned out very widely, and which were grown on half a rood—the site of a former accumulation of dung. The following table shows the results of the experiment:—

[TABLE

* On the Undesirability of Growing very Large Roots. Paper read before Royal Ag. Society of Ireland, by C. A. Cameron.—Irish Farmers' Gazette, June 1873.

Variety of Root.	Average weight of each root.	Water.	Albumenoids.	Sugar.	Pectose, Fibre, &c.	Ash.	Average produce per acre. tons.	cwt.
Mangels.								
1. Carter's mammoth long red mangel,	6 to 7 lb.	84.30	0.80	4.36	9.68	0.86	38	3
2. Hogg and Robertson's long red mangel,	6 to 7 lb.	84.80	0.72	5.55	8.29	0.64	44	12
3. Carter's yellow intermediate mangel,	6 lb.	82.85	0.90	7.40	8.25	0.60	42	8
4. Hogg and Robertson's orange globe mangel,	6 lb.	84.69	0.81	5.60	7.74	1.16	33	3
5. Carter's mammoth, same as No. 1,	18 lb.	92.55	0.40	1.50	4.34	1.21	70	0
Turnips.								
6. Hogg and Robertson's champion swede turnip,	7 lb.	89.06	0.70	9.70		0.54	40	0
7. Select, or Hogg's Norfolk red globe turnips,	6 lb.	90.06	0.62	8.77		0.55	30	0

Useful conclusions are deducible from some of the results in the field and the laboratory, stated in the foregoing table. We learn from them, for instance, that no good results, but rather the contrary, can be obtained by growing monster mangels or turnips. Since the introduction of green-crop husbandry into these countries, it appears to have ever been the farmer's ambition to exceed his neighbours in the production of gigantic mangels and swedes. It has always been the practice, too, of writers in agricultural journals to encourage the growth of roots of abnormal dimensions. This practice has been carried out to an extreme and mischievous extent. By "spoon-feeding" (as it is not inaptly termed) a few roots, it would be easy for a man with several perches of a garden to produce more promising roots for show purposes than a farmer could who grew his 20 acres of roots in an ordinary, and, we may add, a proper, manner. At Brockley Park Carter's mammoth long red mangels were sown in two plots. The mangels sown in one plot were not thinned out widely, but were allowed to grow rather closely together. In the other plot the mangels were supplied with a very large amount of manure, because the plot was the site of a former manure-heap. The mangels here were thinned out widely, so as to allow room for the rapid and extensive development of the roots. The acreable yield of the mangels which had been moderately manured and kept close together amounted to 46 tons 15 cwt., whilst the mangels which had been abundantly manured and widely thinned out produced a crop of about 70 tons per acre. Now, if the large roots and the small ones were equally nutritious, it

would, of course, be desirable to grow the former; but when we compare the composition of the mangels of plot 1 (thickly sown) with those of plot 5 (thinly sown), we find an absolute and important difference in favour of the former. The thickly-sown roots contained 15.7 per cent of solid, or nutritive matter, which, the acreable yield of the crop being 46 tons 15 cwt., was at the rate of 19,782 lb. weight of dry food per acre. The thinly-sown roots contained only 7.47 per cent of solid, or dry matter; and as the acreable return from these large roots was 70 tons, that would yield only 11,681.6 lb. weight of dry food per acre. In producing the large roots, the farmer would incur more expense than if he cultivated the small ones; for instance, he would have to apply more manure, and his cartage would be far greater. If Mr Young grew 10 acres of mangels like No. 5, he would have to cart 700 tons from the field to the stores, and yet he would have in this crop only as much solid food as would be contained in about 450 tons of the smaller mangels, No. 1.

CHAPTER XLIII.

MILK, BUTTER, AND CHEESE.

Cause of the Colour of Milk.—The white appearance presented by milk is generally attributed to the circumstance that this liquid is an emulsion of fats

in a solution of saccharine and albuminous substances. Viewed under the microscope, milk appears to be a colourless liquid, in which are suspended numerous globular bodies, which have been shown to consist nearly altogether of fatty substances. Henle was the first to prove that these so-called fat-globules have albuminous envelopes, an observation since confirmed * by Lehmann, Moleschott, and others. We examined freshly-drawn milk with very high microscopic power (1-30 inch focal length), and found that it contained globules of fatty matter unprovided with membranous capsules. They vanished instantly on the addition of chloroform or anhydrous ether; whilst the globules with envelopes resisted the action of these solvents, unless when treated also with caustic potash. The fat-globules unprovided with investing membranes are, in cow's milk, with few exceptions, smaller than those with envelopes, and rarely exceed 0·0015 inch in diameter. Sometimes they occur abundantly; occasionally they are nearly absent. By violently agitating milk with ether or chloroform for some time, the capsules containing the fats are to some extent ruptured, and their contents set free and dissolved by the ether or chloroform. All the fatty matter cannot, however, be extracted in this way. In the ordinary process of churning the capsules are broken up, and the fats contained in them, being specifically lighter than the other constituents of the milk, ascend to the surface of the liquid to be gathered up as butter. When milk is allowed to rest for some hours, most of the so-called fat-globules ascend and constitute cream; but they do not ascend

* Chemical News, 5th February 1875.

nearly so rapidly as the free fats produced by churning, and therefore the specific gravity of the former is greater, owing evidently to their caseous envelopes.

The colour of milk is due—not to its being an emulsion of fats, but—to the immense number of solid caseous particles which it includes. These objects are so minute that it is difficult to observe the intimate nature of their structure. They appear, however, to be white and translucent. They refract and reflect the light which penetrates the milk, and produce in great part the optical appearance presented by that liquid. There are several facts which tend to prove that it is the insoluble casein investing the fats, and not the latter, which produces the opacity of milk. In the first place, no emulsion of fats with solutions of sugar and albumin simulates the optical properties of milk; secondly, skimmed milk is not so white as buttermilk, and yet it contains from 1.5 to 2 per cent of fats, whilst buttermilk includes only from 0.5 to 0.8 per cent of fats. Buttermilk, containing only 1-200th part of its weight of fats, is a perfectly white and opaque liquid, and it is absurd to suppose that these optical properties are due to the presence of so minute a trace of fats. On the contrary, they are caused by the presence of innumerable particles of solid caseous matter. Skimmed milk is certainly less opaque than new milk, but then, the cream removed from the former contains a large proportion of solid caseous matter. Lastly, if freshly-drawn milk be rendered decidedly alkaline by the addition of solution of caustic potash, and digested for a few hours with ten times its volume of boiling ether, all, or all save a trace, of the fats will be dissolved. If the

ether be separated, a white, non-fatty liquid resembling milk will be left.

Cow's Milk is a solution in water of lactin (page 69); albuminoids, chiefly casein (page 78); and saline matters; with these are mixed the fat-globules and their insoluble caseous envelopes just described. The most contradictory statements as to the reaction of milk have been published; some chemists state that it is alkaline, others that it is acid, whilst a third set of observers affirm its neutral character. Whilst the milk of carnivorous animals is acid, it will in general be found that cow's milk is neutral. Its specific gravity varies from 1028 to 1032. Pure milk rich in fats has a low specific gravity.

Milk varies in Quality.—Milk retained for some time in the udder undergoes partial decomposition; its fats separate from the other ingredients and are in great part kept in the udder during the first stage of milking. As the udder becomes emptier, the milk drawn therefrom becomes richer in cream, and the last portion drawn (the *strippings*) is richest in fats. Reiset found in the first portion of milk drawn from the cow, from 1.8 to 5.9 per cent of fats, and in the strippings from 6.6 per cent to 10 per cent of fats. Peligot, Parmentius, Voelcker, and others have obtained similar results. Milk varies in composition at different periods of lactation, and even of periods of the day. The morning's milk is popularly considered to be the richest, but Voelcker found that the evening's milk was usually slightly richer. He considers that the superiority of the milk at any particular time depends upon the nature and quantity of food which the cows may have consumed during the four or five hours pre-

ceding the milking. Struchmann and Bödeker found 2.17 per cent of fat in the milk of a cow in the morning, 2.63 per cent at mid-day, and 5.42 per cent in the evening. According to Professor Arnold, milk is partly absorbed when kept for a long time in the udder; and he and several extensive dairy farmers in America, assert that cows milked thrice daily produce more milk and butter than if they were milked only twice a-day.

Colostrum is the scientific term given to the first milk (*beastings*) yielded by the cow after calving. It is a turbid, mucilage-like liquid, very alkaline and very rich in casein. The solids vary from 25 to 30 per cent, of which more than one-half consists of casein and albumin. The solids in the colostrum diminish daily, and in about ten days the liquid becomes ordinary milk. During the first month after the disappearance of the colostrum, the quantity of milk yielded by the cow is very large; but in about six weeks after lactation has commenced, the quantity begins to diminish and the quality to improve until the liquid ceases to be secreted. Cows generally "go dry" in about ten months; but, especially if liberally fed, they often continue to yield good milk for several months longer.

Composition of Cow's Milk.—Whilst the milk of individual cows varies very much in composition, the mixed milk of a herd of cows keeps tolerably constant in composition. We have never found the solid matters in the mixed milk of a herd of dairy cows to sink lower than 12 per cent. The milk of fifteen cows was daily examined during a whole year by Müller and Eisenstuch for the Royal Agricultural

Society of Sweden. The solids never sank to 11.5 per cent, and only on four occasions were they lower than 12 per cent. The average composition of the milk of 42 cows kept at Glasnevin Model Farm in 1880 was as follows :—

Water,	86.80
Solid matters,	13.20
Including fats,	3.82
Ash,	0.71

The average yield per cow was 6.37 quarts per morning, and 3.63 quarts per evening = 10 quarts. The percentage of solids varied from 11.5 to 16.8, and of fats from 2.88 to 5.40. The evening's milk was slightly richer than the morning's. The old cows' milk was richest. The milk of country cows is not, on the average, so rich as that of town dairy cows. The proportions of the various ingredients of milk fluctuate—that of the fats most, that of the ash least.

Cream.—When milk is allowed to stand for some time, the greater part of its fat, and of the caseous matter surrounding the fat-globules, ascends to the top, and constitutes *cream*. If the cream be very thick, it will contain from 55 to 65 per cent of water, from 30 to 40 per cent of fats, from 8 to 12 per cent of albuminoids, and from 1 to 2.5 per cent of sugar and ash.

Skimmed Milk is a bluish-white fluid, of specific gravity varying from 1034 to 1037. It contains about 10 per cent of solids, including from 0.6 to 1.5 per cent of fats, and 0.7 to 0.9 per cent of ash.

Testing Milk.—The *lactometer* is simply a hydro-

meter, or instrument for determining the specific gravity of liquids. If milk have a specific gravity of 1030, that of water being 1000 (or unity), then a mixture of equal weights of water and milk would have a gravity of 1015—and so on. This mode of testing is liable to mislead, because the specific gravity of pure milk is not constant. As a rule, milk which is well *watered* has a low gravity; but if milk be both *watered* and *skimmed*, it will retain the normal gravity of pure milk. The reason of this is, that the removal of cream from milk increases the specific gravity of the latter, the fats which form the larger portion of the solids of the cream being lighter than water. The *galactometer* is a cylindrical glass measure. The milk is poured into it until it reaches the highest mark, or *zero*; from this mark there are lines ☰ marked on the glass, the space between each line and that next to it being the one-hundredth part of the volume of the measure. In such a measure-glass the cream of good milk will in general be found to extend from zero down to from 9° to 14°. We have, however, often found pure milk to show only 8° of cream in the galactometer; and we have also observed milk containing from 12 to 25 per cent of added water to throw up 9° to 10° of cream. This test is therefore unreliable. 100 grains weight of milk, placed on a little flat porcelain capsule, and evaporated therein to dryness, should leave a residue amounting to 12 grains weight. If the residue be only 6 grains, then the milk must have been adulterated with its own weight of water; or if 8 grains be the weight of the residue, to the milk must have been added one-half of its weight of water—and so on.

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The capsule may be placed in an oven if there be no danger of overheating the milk residue, or it may be heated over a tin vessel filled with water, kept boiling by means of a spirit-lamp.

Influence of Breed on the Quality of Milk.—It is a general belief that the small-sized kinds of cows are the best for the dairy—that is, that they give most milk for the food consumed. This opinion is not in accordance with the results of special experiments in relation to this point, especially those made in Germany. Thus Baron Ockel, in Frankenfelde, found that Ayrshire cows, weighing on the average 806 lb. each, and Holstein cows, weighing each on the average 1016 lb., consumed, the former 16 lb., the latter 14.6 lb., of lucerne per 100 lb. of their weight. The Ayrshires yielded 5.5 quarts of cream per 100 lb. of lucerne consumed, whilst for the consumption of the same quantity the Holstein cows gave 7.4 quarts. The experiments of Baron Weckerlin, Lehmann, Villeroy, and Rohde, gave similar results. Voelcker states that the milk of the small breeds is richer than that of the large varieties, though the former are not so economical to the dairy farmer. We found the mixed milk of a herd of Alderneys on the farm of Col. Forde, Seaforde, county of Down, to contain per 100 parts—

Water,	84.00
Cheesy matters and sugar,	8.44
Fats,	6.86
Ash,	0.70
	100.00

It gave 20.0 of cream.

Yield of Milk.—According to Weckerlin, a cow 700 lb. weight requires one-sixtieth of its live weight in

hay (or its food equivalent) daily, to maintain her weight; and on this allowance she produces during lactation from four to five times her weight in milk, according to her breed, age, &c. Rohde states that a Holstein cow produces one quart of milk for every 5 lb. of hay which she consumes; and that an Ayrshire cow consumes 9 lb. of hay for each quart of milk produced by her. The difference between the two kinds of cows is extraordinary. Experiments made in the United States * showed that Holstein cows produced nearly $7\frac{1}{2}$ times, and Ayrshire cows $8\frac{2}{10}$ times, their own weight in milk. Villeroy found that cows of different breeds gave per 100 lb. of hay consumed, the following quantities of milk, in quarts:—Dutch, 28.92; Yorkshire, 27.45; Devon, 19.13; Hereford, 15.97; Jersey, 26.33. Lehmann found that the shorthorn was a very superior milch cow; and an Ayrshire dairy herd, composed exclusively of shorthorns, produced 625 gallons of milk annually per head. Professor Wilson, University of Edinburgh, states that the largest recorded produce of milk was that yielded by a cow belonging to the keeper of Lewis jail, and which amounted to 1210 gallons a-year. The seven years' record of a large dairy (that of Mr Harrison of Frocester Court), and other statistics equally reliable, show that from 530 to 550 gallons per annum per cow are the average quantities to be expected.

Influence of Food on the Quality of Milk.—Attempts have been made to increase the relative amount of each of the various ingredients of milk by peculiar methods of feeding the animals producing it. G.

* Transactions of the New York State Agricultural Society for 1871, p. 392.

Kühn and M. Fleischer state that fats added to the rather sparse diet of cows, increased the proportions of all the constituents of their milk, and not that of its fats only. Carbo-hydrates added to their food did not produce an increase of fats in the milk. Nitrogenous food did not increase the proportion of casein in the milk; and the addition of earthy and saline matters to the food of the cow did not cause an increase in the amount of ash in their milk (Weiske-Proskau). Struchmann, who kept dairy cows on a great variety of dietaries, found that most milk was produced by a mixture of 5½ lb. of rape-cake, 25 lb. of oat-straw, and 36 lb. of mangels. He found that 1 lb of rape-cake produced $1\frac{1}{6}$ lb. of milk. It would appear that it is not possible to produce milk very rich in butter, or in cheese, or in any one particular ingredient; but it is certain that abundance of good food, especially if rich in fats, produces milk rich in all its constituents.

COMPOSITION OF THE MILK OF DIFFERENT ANIMALS.

1000 parts contain—

	Water.	Butter.	Cheesy matter.	Sugar.	Mineral matter.
Woman, . .	889.08	26.66	39.30	43.66	1.30
Cow, . . .	870.00	38.00	40.00	45.70	7.20
Goat. . . .	864.90	56.87	35.14	36.91	6.18
Ewe, . . .	830.32	53.31	69.78	39.43	7.16
Mare, . .	903.60	10.55	19.53	62.35	3.97
Ass, . . .	890.12	18.53	35.65	50.46	5.24
Sow, . . .	817.60	58.30	61.80	53.35	8.95

Butter, when pure, consists chiefly of a solid fat termed ***palmitin*** ($C_{51}H_{98}O_6$), and a liquid fat, ***olein***

($C_{57}H_{104}O_6$). It also includes a small proportion of *stearin* ($C_{57}H_{110}O_6$), a solid fat found abundantly in suet and other fatty substances. According to Heintz, butter contains a small quantity of a fat which he terms *butin*. The peculiar qualities of butter are due to the presence of the fats termed *butyrin*, *caprin*, *caproin*, and *capryllin*. Lerch states that in some specimens of butter which he examined he found caproin and butyrin replaced by a fat which he terms *vaccinin*; whilst Heintz asserts that butter contains *myricin*, the most abundant substance in bees'-wax.

Fats are *glycerides* (*glyceryl-ethers*), or compounds of fatty acids with glycerin. The latter substance is a triatomic alcohol, and its 3 atoms of hydrogen are replaceable by 3 atoms of an acid. When a glyceride is heated with potash, the latter takes the place of the glycerin, which is set free, and the fatty acid and potash uniting form *soap*. If, to such a soap, a strong acid be added, the fatty acid will be removed from the potash, and its place taken by the stronger acid. It happens that the fatty acids which characterise butter are volatile under 500° Fahr., and are soluble in water; whilst *stearic*, *palmitic*, and *oleic acids*, common to most fats, are neither volatile nor soluble in water. Otto Hehner proposed that the addition of meat-fats to butter should be detected by determining the amount of insoluble fatty acids in the suspected specimen; and his suggestion has been adopted, and the process worked out, chiefly by Angell, Dupré, and Muter.

Dupré dissolves 5 grammes (about 77 grains) of the dried butter in 100 cubic centimetres (about 3 oz.) of normal alcoholic soda (to be got from Mr F.

Sutton, Norwich, or other supplier of scientific tests, &c.), and allows the mixture to stand over night. The jelly found next morning is to be dissolved in a ½ litre (about 17½ oz.) of water, and hydrochloric acid added until white curds cease to appear. These, when well washed with cold water upon a tared filter, dried (preferably in the exhausted receiver, in which a little vessel of sulphuric acid, to absorb moisture, is placed), and weighed, will give the amount of insoluble fatty acids.

In pure butter the soluble fatty acids amount to from 5 to 6 per cent, and the insoluble fatty acids to from 86 to 89 per cent. In meat-fats (suet, lard, &c.) there are no volatile fatty acids, and the fixed and insoluble fatty acids amount to from 94 to 96 per cent.

Butyrin is inodorous, but the acid (*butyric acid*, $C_4H_8O_2$) which it yields by the treatment above described, or when butter becomes stale, possesses a burning flavour, and an odour resembling that of a mixture of vinegar and rancid butter. *Caproic* acid ($C_6H_{12}O_2$) has an odour somewhat resembling that of the goat—hence its name, from *capra*, a goat. *Caprylic* acid ($C_8H_{16}O_2$) has a feeble but rather unpleasant odour. It is liquid at 59° Fahr. *Capric* (or *rutic*) *acid* ($C_{10}H_{20}O_2$) is a solid fatty substance, fusing at 89° Fahr. Its odour resembles that of caproic acid, and its flavour is very sour and burning. All these acids are present in rancid milk, butter, and cheese. Washing rancid butter in warm water partly removes these acids, and improves the quality of the article.

In summer butter contains more olein than in winter, and its melting-point is therefore lower. Mr James Bell, Principal of the Inland Revenue Chem-

ical Department, has determined * the specific gravity of butter-fats at 100° Fahr., and finds that it is always higher than that of meat-fats. 117 samples of English and Irish butter were examined; and the results showed that their specific gravity usually ranged from 911 to 919. The lowest specific gravity was 909.37; but very few fell below 911. 15 samples of stale butter ranged in specific gravity from 913.57 to 918.15. Beef, mutton, and pork fats, and dripping, range from 902.83 to 904.56. Dupré states that a specimen of butter of less specific gravity than 911 may safely be pronounced adulterated.

Campbell-Brown suggests that the melting-point of butter is a clue to its purity. Heisch found that the melting-point of (24 specimens of) butter varied from 93.8° to 97.35° Fahr.; whilst meat-fats varied from 109° to 120° Fahr. Cocoa-butter melts, however, at 94.82°; and palm-oil at 102.56° Fahr.

Composition of Butter.—As met with in the market, butter contains from 7 to 20 per cent (generally 12 to 14) of water; 70 to 87 per cent (generally 78 to 84) of fats; 0.5 to 4 per cent (generally 0.7 to 1) of curd; and from 0.5 to 15 per cent (generally 2 to 4) of salt.

Butter-making.—When milk is left at rest for some time, its fat-globules rise to the surface in the form of cream. The rapidity with which they rise depends upon the temperature to which the milk is exposed—being quicker in warm than in cold weather. Thus, for example, when milk is set aside it may be perfectly creamed in 36 hours when the temperature of the air is 50° Fahr.; 24 hours at 55°; and from 18 to 20 hours at 68°; while at the temperature of 34° to

* Return to an order of the House of Commons, June 15, 1876.

37° Fahr., it may be kept for three weeks without throwing up any notable quantity of cream. A uniform temperature of 60° is the best.

The cream thus thrown up contains the greater part of the fatty matter of the milk, mixed with a small proportion of curd and much water. The richest cream yields 10 oz. of butter per quart; but, on an average, cream properly churned produces 8 oz. of butter per quart.

The best butter, in flavour and keeping properties, is made from *sweet* cream. In Denmark, the milk is set at a low temperature in order to avoid souring of the cream.

Churning.—When milk or cream is agitated for a length of time, the fatty matter gradually separates from the milk, and collects in lumps of *butter*. There are several circumstances in connection with the churning to which it is of interest to attend.

In the churning of *cream* it is usual to allow the cream to stand in cool weather for several days, until it becomes distinctly sour. In this state the butter comes sooner, and more freely. If, however, the cream becomes too sour, the butter is certain to be inferior. 36 hours appear to be sufficient, even in spring. The butter, when collected in lumps, is well beaten and squeezed from the milk. In some places it is usual also to wash it in cold water as long as it renders the water milky; in other places the remaining milk is separated by repeated squeezings, and by drying with a clean cloth.

Clouted cream may be churned with advantage in the sweet state—the butter separating from it with great ease. Colonel le Couteur states that in Jersey

it is usual to make ten pounds of butter in five minutes from the clouted cream of the Jersey or Alderney cow. Clouted cream is obtained by gradually heating the milk in deep pans, almost to boiling, but so as never to break the skin or *clout* that forms on the surface. The cream is said to be more completely separated by this process than by any other, and a larger quantity of butter to be obtained from the milk.

The whole milk may also be churned, after being allowed to stand till it has attained the proper degree of sourness, which is indicated by the formation of a stiff brat on the surface, *which has become uneven.* This method is more laborious, requiring more time than when the cream only is used; but it has the advantage, as many practical men have found, of yielding five per cent more butter from the same quantity of milk, and of a quality which never varies in winter or in summer. It also requires no greater precautions nor more trouble to be taken in warm than in cold weather.

Temperature.—The temperature at which the whole milk ought to be churned, namely 65° Fahr., is higher than that of the air in our climate, throughout nearly the whole course of the year. The dairymaid has simply to add hot water enough to the milk to raise it to 65° Fahr., and to repeat this every morning of the year, if she churn so often. On the other hand, the temperature of cream, when churned, should not be higher than from 53° to 55° Fahr., a point beyond which the air often rises. It becomes necessary, therefore, in summer, to cool the milk-room in which the cream is churned, and, by churning early in the

morning, to endeavour to keep the cream down to the proper temperature.

Thus, in churning cream, the task of the dairymaid is a more difficult one. In winter, she must add hot water to bring the temperature up to 55°, and in summer must apply cold to keep it down. In this she sometimes fails, and on these occasions the quality of the butter suffers.

Setting the Milk.—When the milk is drawn from the cows it should be carefully strained, and put to the depth of 3 inches into shallow vessels. These are best made of glass, *glazed* earthenware, or tinned iron. It is said that zinc vessels throw up most cream: but we know, as the result of an experimental inquiry, that such is not the case; and as zinc is poisonous, and dissolves readily in sour milk, vessels made of this metal should not be used. Wooden vessels are unsuitable, being with great difficulty kept clean. Lead vessels are largely used, but they are not so good as tinned iron pans. The cream should be skimmed off after the milk has set for twenty-four hours, and any cream that afterwards ascends can be removed by one or more skimmings. When the cream is kept so long on the milk that it becomes sour, the butter made from it is always inferior.

Instead of setting it to form cream, the milk is often churned. In this case it is left for two or three days to turn it sour, or its acidity is hastened by the addition of sour milk. In summer the temperature of the milk is generally sufficiently high; but in winter it must be brought up to 65° Fahr. by the addition of hot water. About thirty minutes' churning suffices for cream, and from one to two hours for

whole milk. Too rapid churning is injurious to the quality of the butter. The motion of the churn should at first be slow—from twenty to twenty-five rotations per minute; but so soon as the cream cracks, then the strokes may be increased to forty, which, when the butter is freely coming, should be reduced to twenty per minute. When the churning has ceased, the buttermilk is drawn off, and a little cold water introduced into the churn, which for a few seconds is again set in motion, and then the butter is taken out of it. Prolonged churning injures the quality of butter by incorporating cheesy matters with it.

During churning milk increases in temperature (from 55° to 60° Fahr., for example), absorbs oxygen, becomes sour, and evolves gas. The vents with which churns are usually provided should be occasionally opened to allow this gas to escape.

Preservation of Butter.—To our taste and smell, butter made from cream has a pleasanter odour and flavour than that made from whole milk; but we think the latter *keeps* better. Either kind, however, soon becomes rancid—1st, by decomposition of the fats; 2d, by conversion of lactin into lactic acid; 3d, by fermentation of casein. These changes are to a great extent preventable by mixing common salt with the butter. The "reason why" salt preserves organic matters is not accurately known, but the antiseptic properties of this substance have been appreciated for thousands of years. The salt is best mixed with the butter in the following way:—The butter, deprived by *very moderate washing* of traces of buttermilk, is spread out in a tub, and the salt shaken over it; the

butter is then turned over on the salt by the lower part of the palm of the hand, and rubbed down until a uniform mixture of salt and butter is obtained. Only one-half of the salt to be used need be at first rubbed in, and the mixture allowed to stand until the next day. When then examined, a quantity of buttermilk will be found exuded, and this being poured off, the rest of the salt may be mixed with the butter.

Bad salt spoils good butter. If salt has a tendency to absorb moisture from the air, and thereby to become damp, it is likely to contain the bitter salt, magnesic chloride ($MgCl_2$). The addition of half a pint of hot water to one stone of salt, will dissolve the greater portion of the magnesic chloride, and the purified salt can be then set to drain.

Butter intended for immediate use requires only about ¼ oz. of salt per lb. to preserve it ; but if intended for exportation, &c., from ½ to ¾ oz. of salt may be used.

Packing Butter.—In packing butter the great object to be attained is the most perfect exclusion of air from this perishable article. In filling the firkin (or other vessel), the butter should be pressed firmly against the bottom and sides. If the vessel be only partially filled, the surface of the butter should be furrowed, so as to allow the next addition to unite the more perfectly with the butter first placed *in situ.* It is better to fill vessels by degrees ; about 6 inches of butter from each churning will be a sufficient quantity, and in a large dairy two or more firkins can be simultaneously filled. When the butter has reached within an inch of the top of the vessel, the remaining space should be filled with dry salt, *not with pickle,*

as is too often the case. Butter does not improve as cheese does by age, therefore the sooner it is sold the better.

The Dairy and its Maid.—There are a great many qualities of butter in the market, and some of them command considerably higher prices than the others. The low qualities are often the result of bad management on the part of the butter-makers or their servants, or of both. Let us consider a few useful points in connection with the dairy and its produce. In the first place, the dairy should not be situate near a pigsty, stable, cesspool, leaking sewer, or dung-heap. Butter is a most delicate article, and readily absorbs, and is injuriously affected by, putrescent organic matters and foul gases. The aspect of the dairy is preferably a northern one, so as to avoid excessive heat in summer. It should be well ventilated, and kept thoroughly clean, but without so lavish an expenditure of water as would keep the place damp and sloppy. The cleaner *everybody*, *animal*, and *thing* in connection with the production of butter is, the better is the butter. The udders of the cow should be washed; her stable (if housed) kept very clean; the milk-vessels should be thoroughly washed both after and before being used. The dairymaid should be clean in person, habits, and clothes; and care should be taken not to employ one whose hands are disposed to perspire too freely. The use of wooden spades in manipulating the butter is desirable, if for no other reason than that *handling* has a tendency to injure it.

Colouring Butter.—Pale butter does not, even when of good quality, usually command so high a price as that which possesses a rich yellow tint. To impart

this colour, a substance termed annatto extract is mixed with it. This compound is prepared by digesting the seeds of *Bixa orellana* in caustic soda, and is now largely manufactured. Saffron boiled in water makes a good colouring material. Annatto is also used to colour cheese.

Cheese, as met with in the market, varies greatly in composition. Good kinds contain from 30 to 35, and inferior kinds 38 to 45, per cent of water; rich sorts include from 25 to 30 per cent of fats, and about the same proportion of albuminates. Poor cheese often contains only 6 per cent of fats, and 40 to 50 per cent of water. The amount of ash varies from 3 to 10 per cent.

Acid of Milk.—When milk is left to itself for a sufficient length of time, it becomes sour and curdles. This takes place sooner in warm weather, and in vessels which have not been cleaned with sufficient care. The sourness is due to a peculiar acid to be found in it, to which, from its having been first observed in milk, the name of *lactic acid*, or acid of milk, has been given. To this acid the sourness of milk is owing. The same acid is produced when crushed wheat—as in the manufacture of starch from wheat—wheaten flour, oat-meal, pease-meal, &c., cabbage and other green vegetables, are mixed with water, and allowed to become sour. It exists in considerable quantity in cider.

Curdling of Milk.—As the milk becomes sour it also becomes thick, the casein which in the fresh milk had been soluble becoming now more and more insoluble. If the milk in this state be thrown upon a cloth and gently pressed therein, a clear liquid

(*whey*) passes through, and the solid matter (*curd*) is retained. The curd when salted, pressed, and dried constitutes cheese.

Casein in fresh milk is soluble in purè water; but it is insoluble in certain acids. If, therefore, hydrochloric acid be added to fresh milk the casein is thrown out of solution. Vinegar and oxalic acid produce the same effect, but if used in excess, dissolve the precipitate which they first produce. If the milk be boiled, the casein is also thrown out of solution, but we have found that all the albuminous matter is not precipitated by heat, a minute quantity remaining in solution. The formation of curd in sour milk is clearly due to the action of lactic acid.

A remarkable way to curdle milk is to add to it the substance termed *rennet*. This is the fourth stomach, salted and dried, of the young calf. The stomach of the young lamb, pig, and hare have the same effect. *Essence of rennet* is prepared by macerating the article in a strong solution of salt. It is largely used by cheese-makers. How it is that rennet coagulates milk we know not; the common explanation, namely, that the rennet converts the lactin into lactic acid which precipitates casein, is incorrect, as has recently been shown by Selmi and Heintz. In fact rennet throws down casein from alkaline solutions.

Varieties of Cheese.—The various kinds of cheese owe their peculiarities to differences in the mode of manufacture and to the nature of the raw material —which may be cream, whole milk, skimmed milk, or buttermilk, or a mixture of two of these substances. Thus we have—

Cream-cheeses, which are made from cream alone,

put into a cheese-vat, and allowed to curdle and drain of its own accord, and without pressure; or, as in Italy, by heating the cream, and curdling with sour whey or with tartaric acid. These cheeses are too rich to be kept for any length of time.

Cream-and-milk cheeses, when the cream of the previous night's milking is mixed with the new milk of the morning, before the rennet is added. The English *Stilton* cheeses, and the small soft *Brie* cheeses, so much esteemed in France, are made in this way.

Whole-milk cheeses, which, like those of Gloucester, Wiltshire, Cheshire, Cheddar, and Dunlop, are made from the uncreamed milk. These cheeses, like the preceding, however, will be more or less rich according to the way in which the curd is treated, and according as the milk is curdled while naturally warm, or is mixed with the milk and cream of the previous evening.

The large 60 to 120 lb. cheeses of Cheshire will not *stand*, will break and fall asunder, if all the cream be left in the milk. About one-tenth of the cream, therefore, is skimmed off and made into butter.

Half-milk cheeses, such as the single Gloucester, are made from the new milk of the morning, mixed with the skimmed milk of the evening before.

Skimmed-milk cheeses, which may either be made from the milk *once* skimmed, like the Dutch cheeses of Leyden—*twice* skimmed, like those of Friesland and Groningen—or skimmed for *three or four days* in succession, like the horny cheeses of Essex and Sussex, which often require the axe to break them, and are sometimes used for certain purposes in the arts.

Whey cheeses, made from the curd which is skimmed off the whey when it is heated over the fire. This is by no means a poor kind of cheese; and good imitations of Stilton are said to be sometimes made by mixture of this curd with that of the whole milk.

Buttermilk cheeses, made by simply straining the buttermilk through a cloth, and then either gently heating the buttermilk, which causes the curd to separate, or, as is sometimes done, by the addition of rennet. This kind of cheese is not unworthy of attention, as it is often richer than that made from milk only once skimmed. It is said to possess some of the other characteristic qualities of good Stilton cheese, which is rather strange.

Some experiments in Cheddar cheese-making conducted at Mr Proctor's dairy, Wallscourt, under the direction of Dr Voelcker, gave the following results: —1000 gallons of milk produced 8 cwt. of cheese, worth £28; the same quantity of milk, partially skimmed, gave 6 cwt. 2 qrs. 16 lb. of cheese, worth £19, 18s. 4d., and 1½ cwt. butter, worth £7 = £26, 18s. 4d.; a third 1000 gallons, skimmed, produced 6 cwt. 24 lb. of cheese, worth £15, 10s. 8d., and 2½ cwt. of butter, £14 = £29, 10s. 8d.; lastly, a fourth 1000 gallons, partly skimmed, and the skimmings added to the balance of whole milk, produced £7, 15s. 4d. worth (3 cwt. 12 lb.) of skim-milk cheese, and £16, 12s. 6d. worth (4 cwt. 3 qrs.) of rich cheese = £24 7s. 10d.

Cheese-making. — The best qualities of Cheddar cheese can be prepared from whole milk. Mr. J. Harding of Marksbury, Somersetshire, one of the best cheese-makers in England, has published his *modus*

operandi in the 23d vol. of the 'Journal of the Royal Agricultural Society.' He places all the milkings of the day together, heats the mixture to 80° Fahr., and adds the rennet. In an hour the curd separates, whereupon a portion of the whey is run off, and heated sufficiently high to enable it to raise the rest of the whey and the curd to which it is returned up to 100°. From the curd, after being thus *scalded*, the whey is drawn off through an outlet in the bottom of the tub or vat. The curd, when it has become somewhat dry, is broken into pieces in a mill, mixed with salt, wrapped in a cloth and transferred to the cheese-press, where each day its wrapper is replaced by a clean cloth. On the third day it is removed to the cheese-room, and kept there in laced bandages for a few weeks. In about three or four months it is perfectly ripe for the table. In Gloucestershire the milk is converted into cheese twice daily. A pint or 1½ pints of rennet are added to each 100 gallons of milk; the temperature of the latter being 80° Fahr. In an hour the curd is separated from the whey; the latter is baled out after the former has been broken up by means of a wire sieve placed at the end of a pole and moved slowly throughout the mass of curd and whey. The curd is next crumbled by the hand, placed in a cloth, and after a preliminary squeeze of twelve hours' duration is salted. It is then returned to the press, in which it is left until the apparatus is required for a fresh charge. Finally, it is allowed to ripen in a dry store. 1 lb. of cheese is a usual product from 1 gallon of milk. 2 lb. of salt are sufficient for 100 lb. of cheese.

It is a mistake to store cheese in a cold, damp

place; it ripens faster and better in a dry room, and at temperatures between 50° and 70°.

Amongst the many recent mechanical aids to the cheese-maker, perhaps the most important is the heating apparatus of Cockey & Sons of Frome. A boiler placed in the cheese-store keeps it warm when required, and supplies steam or hot water to a close chamber placed beneath the vessel containing the milk. This vessel, which may be a "jacketed" tin one, is useful in summer too, for the milk contained in it can be cooled by placing cold water in the outer vessel.

CHAPTER XLIV.

ANIMAL NUTRITION.

Matter and Force.—It has long been known that it is beyond the power of man to annihilate the smallest particle of matter. He can alter its shape, can unite different kinds of matter into new combinations, and resolve compound substances into simpler bodies; but he cannot cause matter to cease to exist. It is only in modern times that it has been experimentally proved that *force* is indestructible. Force, like the matter upon which it acts, may be caused to change its form; but it does not thereby cease to exist, nor does it become diminished in quantity. What is force? Heat is force; so also is light. It

is force which causes matter to be removed from one place to another, produces chemical combinations and decompositions, keeps our bodies warm, sustains our movements, and enables us to see. Gravitation, magnetism, and electricity are force. As matter is perpetually changing its forms, so also is force. Light is converted into heat, chemical force becomes animal motive power.

Functions of Vegetables. — Plants possess the power of absorbing from the air and soil certain kinds of mineral matter, and of elaborating them into organic and organised substances—starch, albumin, &c. The organisation of mineral matter through the agency of plants is effected by force, the plants themselves being merely mechanisms, and incapable of originating force. The sun is the source from which plants obtain the force necessary to their growth; and as they do not move about or require a higher temperature than that of the air surrounding them, they do not expend much of the motive power which they receive from the solar beams. Now, the force which has caused carbonic acid, water, and ammonia, to become sugar, cellulose, oil, albumin, &c., is not destroyed. It is stored up in the plant, which has grown, under its influence, perhaps from a tiny acorn to a gigantic oak. When the matter constituting the plant is disorganised, the force which had organised it reappears in one or more forms. If the plant be an oak, it can be *burned*, and the force stored up in it set free as light and heat, which may be directly used for many purposes, or converted into mechanical power by means of the steam-engine.

Functions of Animals.—It is necessary that ani-

mals should move about in search of their food; and all of them require to have their bodies kept at a higher temperature than that of the air surrounding them. If a vegetable, instead of being directly burned in a furnace, be disorganised in the body of an animal, the force stored up in the former is set free, and assumes the forms of heat and *animal motive power*. The functions of plants and animals are therefore opposite. The former continuously organise matter and accumulate force; the latter incessantly disorganise matter and expend force. There are many other functions discharged by animals and plants not necessary to be discussed here.

The force contained in the food consumed by animals is disposed of in various ways. A large portion invariably becomes heat, which escapes from the body. Much of it is expended in causing motions (contractions) of the muscles, some of which are involuntary, such as, for example, those of the heart and lungs. The process of reorganising food, so as to assimilate it to the nature of the animal fed upon it, also involves expenditure of force; and the maintenance of mental or nervous power is also sustained by force derived from food. In some cases—as, for example, when a man or a horse works hard—most of the force contained in his food is used up in enabling him to perform his labour.

How Vital Action is sustained.—Carbonic acid, water, and ammonia are, as we have seen, decomposed by plants; a portion of the oxygen contained in the two former is given off, and the rest, together with all the carbon, hydrogen, and nitrogen, is retained and converted into organic substances. In the animal,

these substances are reunited with oxygen and converted into mineral substances and urea (which is almost a mineral). The force expended in producing the organic substances is set free in the animal mechanism in the form of heat and energy.

Action of Oxygen upon the Body.—Atmospheric air contains 21 per cent, by volume, of oxygen, and about 0.04 per cent of carbonic acid. In the act of inspiration a man takes into his lungs from 30 to 40 cubic inches of atmospheric air, and he *expires* from his lungs, a few seconds afterwards, very nearly the same volume of air. In the course of twenty-four hours, nearly 400 cubic feet of air are taken into the lungs. If the expired air be examined, the oxygen will be found diminished by nearly 5 per cent, and the carbonic acid increased one hundred fold. The oxygen has been used up in converting the carbon and hydrogen of the tissues and food into carbonic acid and water. It is by this combustion—which, however, is a very slow and gentle one—within the body that its high temperature and vital functions are maintained. Air expired from the lungs is poisonous; and hence the necessity of perfectly ventilating not merely the dwellings of man, but also the places in which the lower animals are housed. It is a fact worth noticing here, that the weight of oxygen taken into the lungs in twenty-four hours exceeds that of the (dry) food taken into the stomach.

Animal Heat.—As the heat of the body is tolerably uniform, the decomposition of the organic matter which produces it must occur equably throughout the system. The blood of man has a temperature of about 99° Fahr.; that of birds from 106° to 108°; and of

warm-blooded reptiles from 84° to 86°. The bodies of animals, like other masses of heated matter, lose heat by radiation and conduction. To prevent waste of heat, nature has clothed the bodies of animals with hair, fur, feathers, and other light, porous substances through which heat passes with difficulty. It is the almost absolutely non-conducting material — a fine *down*—which covers the body of the eider-duck that enables it to resist the extreme cold of the waters of the icy sea, and the still colder atmosphere of the arctic circle. As animal heat is kept up by consumption of food, shelter and warmth are to some extent substitutes for food. It has been suggested that fattening animals should be kept in houses supplied with artificial heat; but this plan seems hardly necessary, and certainly would not, in the British Islands at least, where fuel is dear, be an economical one. It is sufficient to protect the animals from the piercing blasts, the cold rain, and the snow-drifts of winter. It is well to bear in mind that animals are not likely to get fat, however abundantly supplied with food, if allowed to lie out in open spaces in very cold or very wet weather.

Animal Force.—One pound weight of carbon produces, when perfectly oxidised (burnt), sufficient heat to increase the temperature of 14,200 lb. of water one degree, on Fahrenheit's scale of temperatures, or to convert 12.65 lb. of water at 100° (about the temperature of the body of a man) into steam. As about 2½ lb. of water in the form of vapour daily leave the body, only about 3 oz. of carbon are expended in the production of that amount of vapour. When 1 lb. of water falls from a height of 772 feet, its

temperature is increased thereby one degree, and the heat required to raise 772 lb. of water one degree of temperature is sufficient to lift 772 lb. of water, or any other substance, to a height of one foot. From the above data, we conclude that the combustion of one ounce of carbon in the body of an animal evolves force sufficient, if completely utilised, to raise a weight of 685,150 lb. one foot high. Although in the animal mechanism force is economised to a far greater extent than in the steam-engine or any other artificial machine, yet it is not fully utilised. According to Professor Haughton, one-third of the force applied through the muscles of man is lost by friction of the tendons. The calculations of Haughton, Donders, and others, show that a man engaged in hard out-door work expends daily in his labour force sufficient to raise 350 tons of matter one foot high. It has been shown that the energy daily expended in maintaining the indispensable vital functions of a man is equal to that required to raise 133 tons one foot high.

Some physiologists believe that the muscle is a machine in which the heat derived from the oxidation of the blood or other organic matter is converted into force; other physiologists maintain that animal force results from the oxidation of the muscles themselves. It is probable that both blood and muscles furnish by their oxidation, heat and mechanical power. It is remarkable that during severe exertion, the excretion of nitrogen is not increased; but shortly after the exertion is concluded, there is a larger elimination of nitrogen (as urea) from the system. It is certain that animals hard-worked require a liberal supply of nitrogenous food, and probably derive the greater portion

of their muscular energy from the decomposition of the muscles themselves.

Assimilation of Food.—The food of an animal, whether it be herbivorous or carnivorous, invariably contains albuminoids, fats, and saline substances. In the case of the herb-eating animals, their food is usually poor in fat. To compensate for this deficiency it contains carbo-hydrates in abundance. The consumption of fat in the bodies of carnivorous animals contributes greatly to keep up their temperature, and enables them to move about; and it is probable that the carbo-hydrates act similarly in the bodies of the herbivora. With few exceptions, the carnivorous animals refuse to eat the carbo-hydrates.

Assimilation of Fat.—According to Voit, Pettenkofer, and Bischoff, the fat of animals, even of the herbivora, is chiefly derived from the albuminous constituents of their food. From experiments with dogs they conclude that carbo-hydrates are not converted into fats, but that, being oxidised in the animals' bodies, and force evolved from them, they conserve the fat. They assert that fat is one of the first products of the decomposition of albumin. Whilst excess of starch passes out of the body in the form of water and carbonic acid, an excess of fat is deposited in the tissues. There is no relation between the amount of carbo-hydrates consumed and of fat put up; but there is one between the amount of albuminates consumed and of fat stored up. Voit and Pettenkofer consider that 175 parts of starch equal 100 parts of fat in producing heat and animal motive power. Stopmann and Kühn agree with Voit

and Pettenkofer. Blondeau, Hoppe, and Kemmerich assert that in the animal economy casein produces fat. J. Bauer points to the fact that animals, when poisoned with phosphorus, rapidly form fat out of their ordinary food. According to Subotin, the milk of bitches is richest in fats when the animals are abundantly supplied with flesh.

Weiske and Wildt conclude from the results of their experiments upon pigs that the animals increase both in proteids and fats by the use of albuminates.

As arguments in favour of the view that albuminoids produce fats, attention is called to the fact of the fatty degeneration of muscles, and of the transformation of lean flesh into adipocere, a fatty substance.

According to Payen, Dietrich, and König, the addition of fats to cellulose increases its digestibility.

Many years ago, J. Liebig stated that the fat of the herbivora was mainly derived from carbo-hydrates, though he admitted that a small proportion of it might be formed from albuminoids. H. Liebig—relying chiefly upon experiments with cows made by Knop, Arendt, and Behr—asserts that the carbohydrates constitute the chief source of the fat of the herbivora. Dumas, Boussingault, Persoz, Lehmann, Grouven, and Milne-Edwards, from the results of experiments upon various kinds of animals, arrived at the same conclusion. Bensch and Playfair deny Subotin's assertions above quoted. Lawes and Gilbert, from the results of elaborate quantitative experiments with herbivorous animals, have come to the conclusion that the fat of those animals is chiefly derived from carbo-hydrates, but that it may also be

in part formed from albuminates, especially when they are in excess and the carbo-hydrates are deficient. Ranke found that with the most liberal meat diet he still lost fat. According to Lawes and Gilbert, 2½ parts of carbo-hydrates are equal in nutritive power to 1 part of fat.

Assimilation of Albuminoids.—In a well-regulated diet the nitrogenous and non-nitrogenous foods are exactly proportioned to the wants of the body; but it very frequently happens that either of these classes of aliments is consumed in excess. It is known that a man of average weight, and performing moderate work, requires 300 grains of nitrogen daily in his food. This amount is contained in somewhat more than 4 lb. of bread. If a man were confined to a bread-and-water diet, he would require to consume at least a quartern-loaf daily. In 4 lb. of bread there are about 9000 grains of carbon; and as a man requires only 4600 grains weight daily of that element, there would be twice as much in the quartern-loaf as he could utilise.

Use of Water.—The greater portion of the weight of an animal is made up of water. This liquid should be given in a pure state to the domestic animals. According to Henneberg, excess of water causes an increased excretion of nitrogen by the kidneys and a diminished assimilation of nitrogen.

Saline Foods.—All animals require a certain amount of common salt, earthy phosphates, potash compounds, and some other mineral substances. The ordinary food of every species of animal usually contains, in adequate, and often in excessive, proportions, the inorganic matters necessary to their existence.

In the case of herbivorous animals and of man, common salt, which is absolutely indispensable to them, is not always present in sufficient quantity in their ordinary food. No doubt the instinctive longing which animals have for common salt in a purely mineral form is a wise provision of nature, as it is not always to be got in the vegetable foods which the animals consume. A small quantity of salt is often added to the food of fattening animals, especially pigs. Liebig states that salt in excess retards the fattening of animals. According to Forster, the amount of salines consumed in food is usually in excess of the requirements of the system. The want of a sufficient amount of salt in its food has, however, been often found to cause great injury to an animal. Deficiency of mineral matters in food causes muscular exhaustion. It can hardly be affirmed that the proper quantities of saline matter in dietaries have been established.

Horses digest from 46 to 58 per cent of the total organic matter of hay, 62 per cent of that of pasture grass, 72 per cent of that of oats, and 91 per cent of that of maize. Sheep digest larger proportions of hay and grass, and about the same of grain. The sheep and ox are much better able to digest woody fibre.—(Wolff.)

Composition of Animals.—*The bones* of animals consist of earthy phosphates and carbonates, a minute quantity of common salt, and a large proportion of organic matter. When dried, about one-third of bone consists of organic matter, of which by far the greater portion is composed of *ossein*, which by boiling becomes gelatine. The weight of the bones (skeleton)

of man is to that of the whole body as 10.5 to 100 and as 8.5 to 100 in woman. The bones give strength to the softer portions of the body, protect vital parts of it—such as, for example, the brain and lungs—and, together with the muscles, form the levers by which locomotion and other movements are effected.

Flesh owes its red colour to the presence of blood; washed with water for some time, the blood and soluble albuminoids are removed, and a nearly white substance, chiefly composed of fibrin (p. 76) and fat, is left. If very lean flesh be kept for some hours at a temperature of 212° it loses nearly three-fourths of its weight: the loss is due to evaporation of water. The small proportion of flesh which dissolves in water consists of salts of the blood (chiefly magnesic, calcic, and potassic phosphates and common salt), albumin, peculiar nitrogenous crystallisable substances termed *kreatin* and *kreatinin; inosin*, or "muscle-sugar," and a few other substances. Fat accumulates in certain parts of the body, but it is also diffused, often in large proportion, throughout the muscular tissue. Lawes and Gilbert have analysed the carcasses of animals used as food, and have found that, even in the leanest of them, fat is more abundant than nitrogenous matter. In fact *butcher's meat* is really more a carbonaceous, than a nitrogenous, food, and is often less nitrogenous than food composed of bread-stuffs.

In the following table are given the analyses of the edible portions of ten animals examined by Lawes and Gilbert. The whole carcasses were somewhat richer in nitrogen, chiefly on account of their hides and hooves.

COMPOSITION OF EDIBLE PORTION OF THE CARCASSES OF OXEN, SHEEP, AND PIGS.

Description of Animal.	Mineral matter.	Dry nitrogenous compounds.	Fat.	Dry substance.	Water.
Fat calf,	4.48	16.6	16.6	37.7	62.3
Half-fat ox,	5.56	17.8	22.6	46.0	54.0
Fat ox,	4.56	15.0	34.8	54.4	45.6
Fat lamb,	3.63	10.9	36.9	51.4	48.6
Store sheep,	4.36	14.5	23.8	42.7	57.3
Half-fat old sheep,	4.13	14.9	31.3	50.3	49.7
Fat sheep,	3.45	11.5	45.4	60.3	39.7
Extra fat sheep,	2.77	9.1	55.1	67.0	33.0
Store pig,	2.57	14.0	28.1	44.7	55.3
Fat pig,	1.40	10.5	49.5	61.4	38.6
Means of all,	3.69	13.5	34.4	51.6	48.4

Blood is a very complex substance. Examined through a powerful microscope it presents the appearance of a colourless liquid containing immense numbers of small flat red disks. Shortly after blood has been withdrawn from the body, the small amount of *fibrin* which is in it solidifies, or clots, and entangling with it the red disks, leaves a nearly colourless liquid. There are in 1000 parts of blood about 780 parts of water, and 220 parts of solid matters, of which more than one-half consists of blood-disks, more than one-fourth of albumin, and about one-seventh of extractive matter and salts. In the blood of the carnivora the phosphates, and in that of the herbivora the carbonates, of metals abound; whilst in both, common salt exists in about the same proportions.

Brain contains about 80 per cent of water, 7 of albumin, 5 of peculiar substances termed *lecithin* and

cerebrin, and various fatty substances. In the brain phosphorus is rather abundant, and appears to exist in a very low form of oxidation.

Digestion. — Herbivorous animals are furnished with powerful, blunt teeth, adapted for the purpose of crushing and grinding into a pulp the hard fibrous food which they chiefly subsist upon. The structure of their jaws is such that instead of opening and closing after the manner of a pair of scissors (as the jaws of the carnivora do), they move sideways as well as up and down. These movements enable the broad surface of the teeth to work like millstones, as it were, and so to pulverise or reduce to pulp the hardest and toughest kinds of food. The saliva of the herbivora is very abundant, in order that the dry food which the animals often use may be well moistened. The saliva contains a peculiar nitrogenous substance termed *ptyalin*, which has the property of converting starch into a kind of sugar, and thereby rendering it more easy of digestion. In the saliva of the flesh-eating animals, there is no ptyalin, because they do not eat starch.

In the stomach food is subjected to a peculiar movement somewhat like that of milk in the process of being churned. This helps to break up its structure. It speedily becomes mixed with *gastric juice*—a sour liquid, which is poured into the stomach in great abundance as soon as food is introduced into that organ. *Pepsin* is a nitrogenous principle peculiar to the gastric juice. It is a ferment, and under its influence the food soon enters into a species of fermentation, and becoming nearly fluid, forms a substance termed *chyme*. From the stomach the chyme passes

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Half-fat old sheep,	4.13	14.9	31.3	50.3	49.7
Fat sheep,	3.45	11.5	45.4	60.3	39.7
Extra fat sheep,	2.77	9.1	55.1	67.0	33.0
Store pig,	2.57	14.0	28.1	44.7	55.3
Fat pig,	1.40	10.5	49.5	61.4	38.6
Means of all,	3.69	13.5	34.4	51.6	48.4

Blood is a very complex substance. Examined through a powerful microscope it presents the appearance of a colourless liquid containing immense numbers of small flat red disks. Shortly after blood has been withdrawn from the body, the small amount of *fibrin* which is in it solidifies, or clots, and entangling with it the red disks, leaves a nearly colourless liquid. There are in 1000 parts of blood about 780 parts of water, and 220 parts of solid matters, of which more than one-half consists of blood-disks, more than one-fourth of albumin, and about one-seventh of extractive matter and salts. In the blood of the carnivora the phosphates, and in that of the herbivora the carbonates, of metals abound; whilst in both, common salt exists in about the same proportions.

Brain contains about 80 per cent of water, 7 of albumin, 5 of peculiar substances termed *lecithin* and

cerebrin, and various fatty substances. In the brain phosphorus is rather abundant, and appears to exist in a very low form of oxidation.

Digestion. — Herbivorous animals are furnished with powerful, blunt teeth, adapted for the purpose of crushing and grinding into a pulp the hard fibrous food which they chiefly subsist upon. The structure of their jaws is such that instead of opening and closing after the manner of a pair of scissors (as the jaws of the carnivora do), they move sideways as well as up and down. These movements enable the broad surface of the teeth to work like millstones, as it were, and so to pulverise or reduce to pulp the hardest and toughest kinds of food. The saliva of the herbivora is very abundant, in order that the dry food which the animals often use may be well moistened. The saliva contains a peculiar nitrogenous substance termed *ptyalin*, which has the property of converting starch into a kind of sugar, and thereby rendering it more easy of digestion. In the saliva of the flesh-eating animals, there is no ptyalin, because they do not eat starch.

In the stomach food is subjected to a peculiar movement somewhat like that of milk in the process of being churned. This helps to break up its structure. It speedily becomes mixed with *gastric juice*—a sour liquid, which is poured into the stomach in great abundance as soon as food is introduced into that organ. *Pepsin* is a nitrogenous principle peculiar to the gastric juice. It is a ferment, and under its influence the food soon enters into a species of fermentation, and becoming nearly fluid, forms a substance termed *chyme*. From the stomach the chyme passes

into the *duodenum*, an intestine one foot long in man, and two feet long in the horse, in which latter animal it is succeeded by nearly 90 feet in length of intestines. *Bile* from the liver, and a liquid containing another nitrogenous principle, *pancreatin*, from the *pancreas*, or "sweetbread," flow into the duodenum. Albuminous substances are digested in the stomach, but the fats of the chyme are only affected by the liquids found in the duodenum. According to Radziejewsky, who has recently investigated the matter, the fats are converted into soaps by the action of the intestinal fluids, and the soaps are subsequently decomposed during the circulation of the blood, and their fats deposited and assimilated.

Starch is acted upon by the fluids in the duodenum, and converted into sugar. The food in this organ becomes more homogeneous and liquid, and is now termed *chyle*.

A portion of the broken-down food is absorbed from the stomach into the blood, but a large proportion is taken up from the intestines, especially from the duodenum—through minute, hair-like tubes, termed *villi*, and glands, termed the *mesenteric*—by the *lacteals*. These are small vessels, so named because they are filled with a milk- (in Latin, *lac*) like liquid. From the lacteals the chyle, passing through various channels, merges into and becomes indistinguishable from the blood. The portions of the food which are not converted into chyle pass downwards, and out of the body. The portions which are digested and assimilated are subsequently disorganised and converted chiefly into water, carbonic acid, and urea.

Much of the impurities in the blood is removed by the liver, through which the great river of life sends a large stream. The carbonic acid and water formed in the body are partly got rid of through the skin, partly by means of the lungs. The urea is eliminated from the blood by the kidneys. The blood which flows in *veins* towards the lungs is dark-coloured and contains carbonic acid. In the lungs its carbonic acid becomes replaced by oxygen; it acquires thereby a bright red colour, and flows away from the lungs in vessels termed arteries. These movements of the blood are kept up almost wholly by the contractions of the heart, which is a powerful hollow muscle, and through which the blood is incessantly passing, and in large quantities.

Some animals, such as the ox, have four stomachs. The paunch, or first stomach, is by far the largest; to the right and front of this viscus is the second stomach (the *reticulum*, or honeycomb). In these the food is deposited after a hasty mastication, and from them it is recovered into the mouth when the animal *ruminates*, or "chews the cud." The third stomach (*manyplies*) is connected with the second stomach and the gullet, and—at its lower part—with the fourth stomach, or *rennet*. The food on being a second time swallowed passes through a small section or canal of the gullet, direct into the third stomach. The food which in the first instance is swallowed is bulky, and by pressing upon the gullet dilates its lower aperture, and thus makes a way for itself into the paunch.

CHAPTER XLV.

FOOD AND DIETARIES.

Classification of Foods.—Liebig divided foods into two great groups: 1st, *Plastic nutritive materials*, or *Flesh-formers;* 2d, *Respiratory*, or *Heat-giving materials*. To the first class belong nitrogenous foods, to the second, non-nitrogenous substances. Liebig believed that the plastic nutritive materials produced by their decomposition force, or energy, and the non-nitrogenous substances, animal heat. It is now generally believed that heat and energy are produced from both nitrogenous and non-nitrogenous aliments. It is usual to classify food-constituents as follows: *Proteids*, or *albuminoids* (gluten, casein, &c.); *Gelatigenous substances* (ossein, chondrin, &c.); *Fats;* and *Mineral matters*—and in the case of vegetable substances, *Carbo-hydrates;* and *Fibre* (cellulose, &c.)

Dietaries.—We know the amount of heat or its equivalent in mechanical power which is produced not merely by the combustion of carbon and hydrogen, but by that of muscle and other animal substances, and of vegetable products. On data of this kind furnished by Frankland, Andrews, Despretz, &c., E. Smith, Playfair, Vierordt, and others, have constructed dietaries for man, and some of the domesticated animals. Such dietaries are supposed to be capable of furnishing to the animal just as much food as is necessary to maintain its vital functions and enable it to perform a certain amount of work. Cal-

culated dietaries are very useful, but they are not always strictly reliable. For example, the force which the oxidation (combustion) of food yields outside the body is not fully obtained by its combustion within it. In the case of lean flesh, Frankland found that only two-thirds of the force stored up in it were evolved within the body; therefore the excrementitious matters into which flesh used as food is converted are still capable, when burned, of evolving a considerable amount of heat and force. The food, too, may not be very digestible, and therefore may in great part pass out of the body unoxidised. Notwithstanding these and other drawbacks, dietaries constructed upon the data afforded by the combustion of foods, are of great utility in many cases.

Ingesta and Egesta.—Pettenkofer fed a dog weighing 72 lb. with 1500 grammes (3.3 lb.) daily. The animal consumed daily 477.2 grammes* of oxygen (from the air); the total *ingesta* was therefore 1977.2 grammes, or nearly 4¼ lb. The *egesta* (the substances that passed *out* of the body) were found to weigh 2011.7 grammes,—of which urine formed 1075 grammes; fæces, 40.7 grammes; carbonic acid (per skin and lungs), 538.2 grammes; water (per skin and lungs), 354.8 grammes; carburetted hydrogen and hydrogen (per skin and lungs), 13 grammes.

Dietaries for Man.—According to E. Smith and other authorities, the average diet of a British pauper contains 3¼ oz. of proteids, and 8¼ oz. of carbon; that of the British soldier, 5 oz. of proteids, and 10 oz. of carbon. Hard-working men of the labouring classes consume 10½ oz. of carbon, and 4 oz. of

* The gramme is equal to 15.44 grains, or about $\frac{1}{28}$ oz.

proteids daily. It is said that the English navvies, who during the Crimean war constructed the railway to Balaclava, consumed about 5 oz. of albuminoids daily. The amount of work which they performed literally "astonished the natives."

Dietaries for the Horse.—According to Playfair, a horse requires $29\frac{1}{8}$ oz. of albuminoids when at rest, and 27 oz. additional when at work. As this animal performs as much work as that accomplished by 7 or 8 men, it requires 7 or 8 times as much carbon and albuminoids. If a horse consume 56 oz. of albuminoids, it will require about 140 oz. of carbon.

Professor Dick states that an idle horse requires only 12 lb. of hay and 5 lb. of oats daily. According to Low, a horse works well when fed upon a mixture of 120 to 130 lb. of equal parts of chopped hay, chopped straw, bruised grain, and steamed potatoes. Mr Mechi feeds his farm-horses in winter on a weekly ration of 49 lb. of cut hay, 70 lb. of bruised oats, 210 lb. of mangel-wurzel, straw *ad libitum*—all costing 7s. 6d. (Agricultural Gazette, 25th Nov. 1865.)

A. Sausen states that when the food consumed by an animal at rest is known, the quantity necessary for the performance of a stated amount of work may be found by the following formula, $P = \frac{W}{C}$, P standing for proteids, W for the work, C for the mechanical equivalent of the nutritive unit. This formula has been founded upon data furnished by the General Omnibus Company of Paris.

Dietaries for the Ox. — According to Lawes and Gilbert, the daily food of an ox weighing 1400 lb. should include 55 oz. of albuminoids, 232 oz. of non-nitrogenous matters (fat-formers), and 29 oz. of

mineral matters. Lighter animals of course require proportionately less food. The following are a few of the dietaries of fattening cattle adopted by well-known stock-masters: 1st, 3 to 4 lb. of oilcake, turnips and straw *ad libitum;* 2d, 2 lb. of oilcake, 2 lb. of oats, and straw and roots at pleasure; 3d, 3 lb. of cut straw and 3 lb. of bean-meal, cooked together, and given along with 84 lb. of turnips. Mr Edmonds, of Cirencester, gives 2 parts of hay and 1 of straw cut into chaff. Of this mixture cattle of average size eat about 5 bushels daily, together with 4 to 5 lb. of oilcake and half a peck of mixed meal, barley, and peas or beans. Mr Mechi gives 2 cwt. of swedes (sliced), 7 lb. of oilcake, 3 lb. of boiled linseed, 1 lb. of barley-meal, and 12 lb. of chaffed wheat-straw: this is certainly a liberal diet even for a fattening bullock. Mr Simpson, of Cloona Castle, county of Mayo, gives 72 lb. of turnips at 5.30 A.M., the same quantity at 2 P.M., and an intermediate meal, consisting of 2 lb. of oilcake, some crushed grain, a little hay, and straw *ad libitum.*

Milch Cows require abundance of food, which, however, need not be of an exceptional nature. It has already been shown (page 441) that it is not possible to produce by any system of feeding an increase in the relative proportion of any one of the solid ingredients, but that a generous diet augments the yield and improves the general quality of the secretion. No greater mistake could be made in dairy husbandry than to stint the fare of the cow, though such is by no means uncommon. In summer, when the animals are out in good pastures, they require nothing else; but when the herbage is poor and sparse, their scanty

diet should be supplemented with artificial food of some kind.

Mr Horsfall (whose papers upon dairy farming in the Journal of the Royal Agricultural Society of England are well deserving of careful study) feeds his herds as follows: Each cow receives 9 lb. of hay, 6 lb. of rape-cake, 1 lb. each of malt-combings and bran, and 28 lb. of roots or cabbage. The food (except roots and hay) is given in a mixed, cooked state, and whilst warm, to the animals. In addition to this food, a cow in full milk receives 2 lb. of bean-meal daily, and cows not in full milking order smaller quantities of this article.

Calves require a diet in which the nitrogenous elements are if anything in excess. They should be frequently fed, the demands of the system of growing animals upon food being almost incessant. In winter they should be kept in a warm place, as they, in common with all young animals, are not capable of resisting cold so well as the adult animal is. If not intended early for the shambles, the steers should be allowed plenty of exercise. Those that are to be made bullocks of do not require so much exercise, or indeed so much attention. Pure air and good water are of even greater importance than exercise in the case of young animals. They are often huddled together in houses altogether insufficient in size, and in which the atmosphere is almost constantly impure from the products of respiration.

Mr Hope, of Fenton Barns, treats his steers as follows: They are supplied with turnips, and a little meal and salt, and after 6 weeks, 3 lb. of oilcake is given to each daily, the allowance being gradually in-

creased to 6 lb. They are frequently given potatoes, in unlimited quantities.

Under the mistaken idea that early exposure to cold renders the calf hardy, it is often turned out in early spring into the fields. Exposure to the sharp frosts of spring often injures the constitution of young animals, and renders them more liable to contract disease. It is important that every young animal should at first be supplied with abundance of milk.

Milk is a true food. It contains sugar, casein, saline matter, and fat—a portion of each of those classes of substances on which the herbivorous races live in the most healthy manner. But the provision is very beautiful by which the young animal—the muscle and bones of which are rapidly growing—is supplied, not only with a larger proportion of nitrogenous food, but also of bone-earth, than would be necessary to maintain the healthy condition of a full-grown animal of equal size. The milk of the mother is the natural food from which its supplies are drawn. The sugar of the milk supplies the comparatively small quantity of carbon necessary for the respiration of the young animal. As it gets older, the calf or young lamb crops green food for itself to supply an additional portion. The curd of the milk (*casein*) yields the materials of the growing muscles and of the organic part of the bones; while along with the curd, and dissolved in the liquid milk, is the phosphate of lime, of which the earthy part of the bones is to be built up. A glance at the composition of milk (page 438) will show us how copious the supply of all these substances is,—how beautifully the composition of the mother's milk is adapted to the wants of her infant offspring.

Effect of Dairy Husbandry upon the Soil.—And whence does the mother derive all this albuminoid and bone-earth, by which she can not only repair the natural waste of her own full-grown body, but from which she can spare enough also to yield a large supply of nourishing milk? She must extract them from the vegetables on which she lives, and these again from the soil.

The quantity of solid matter thus yielded by the cow in her milk is really very large, if we look at the produce of an entire year. If the average yield of milk be 3000 quarts, or 750 gallons, in a year (every 10 gallons of which contain bone-earth enough to form about 7 oz. of dry bone), then by the milking of the cow alone we draw from her the earthy ingredients of 33 lb. of *dry* bone in a year. These are equal to 40 lb. of common bone-dust, or 3⅓ lb. *in a month*; and these she draws necessarily from the soil.

If this milk be consumed on the spot, then all returns again to the soil on the annual manuring of the land. Let it be carried for sale to a distance, or let it be converted into cheese and butter, and in this form exported—there will then be yearly drawn from the land, from this cause alone, a quantity of the materials of bones which can only be restored by the addition of 40 lb. of bone-dust to the land. If to this loss from the milk we add only 10 lb. for the bone carried off by the yearly calf, the land will lose by the practice of dairy husbandry as much bone-earth as is contained in 50 lb. of bone-dust—or in 45 years every imperial acre of land will lose what is equivalent to a ton of bones.

After the lapse of centuries, therefore, we can easily understand how old pasture-lands, in cheese and dairy countries, should become poor in the materials of bones—and how in such districts, as is now found to be the case in Cheshire, the application of bone-dust should entirely alter the character of the grasses, and renovate the old pastures.

Sheep.—Voelcker found that 4 sheep, weighing on the average 145½ lb. each, consumed each during 48 days, 16.3 oz. of clover, 4.08 oz. of linseed-cake, and 312 oz. of mangel-wurzel. This diet would afford to each animal 1.9 oz. of flesh-formers (proteids), 53.4 oz. of non-nitrogenous matters (carbo-hydrates, &c.) and 4.83 oz. of mineral matter. Upon this diet the increase in the weight of the 4 animals was on the average 17.875 lb. each.

According to Mr Mechi, 1 lb. of mutton is in general produced by the consumption of 7 lb. of rape-cake, linseed-cake, or beans. Mr Bruce asserts that a pound of oilcake eaten by a sheep of 9 stones weight reduces its consumption of roots by one-third. He further states that the health of the sheep is greatly improved by the use of oilcake.

The consumption of 1 ton of roots produces on the average 14 lb. of mutton, or of beef.

What becomes of the Food ?—A large proportion of the food which an animal eats is utterly used up in keeping its body warm and maintaining its vital movements. The food which is not used for this purpose either passes out of the body or is retained therein, being converted into "permanent increase." It can hardly be asserted that in ordinary dietaries the different ingredients are so nicely balanced that

the increase in the weight of the animal is derived equably from all the ingredients of its food. The "flesh-formers" at one time may be in excess, and at other times the carbo-hydrates may be superabundant. In general, mineral matter is used in greater quantity than it is required. An excess of albuminoids in food is not so wasteful as an over-supply of carbo-hydrates; because, whilst the former is to a great extent recoverable as ammonia in the manure, the latter leaves the body in a form in which it is practically worth next to nothing.

The quantity of food consumed by the ox is in general from 11 to 13 lb. per 100 lb. of its weight; by the sheep, from 14 to 16 lb.; and by the pig, from 26 to 30 lb. Lawes and Gilbert found that pigs whilst fattening stored up about 7½ per cent of the weight of the albuminous portion of their food, whilst sheep retained but 5 per cent of it in permanent increase. Thus 95 per cent of the albuminoids consumed by the sheep passes of in the excretions of the animal. From Lawes and Gilbert we also learn that pigs retain permanently about 20 per cent, sheep 12 per cent, and oxen 8 per cent of the weight of the (*dry*) food supplied to them. The relative increase in the proportion of their fatty, &c., constituents whilst fattening is shown in the following table :—

Cases.	Estimated per cent in increase whilst fattening.			
	Mineral matter (ash).	Nitrogenous matters (dry).	Fat (dry).	Total dry substance.
Average of 98 oxen,	1.47	7.69	66.2	75.4
Average of 348 sheep,	1.80	7.13	70.4	79.53
Average of 80 pigs,	0.44	6.44	71.5	78.40

Preparation of Food.—The horse often expends no inconsiderable amount of muscular force in grinding the hard oats and wiry hay supplied to him, and thus his owner is deprived of a portion of the motive power which the animal is capable of yielding. It is without doubt economical to bruise the oats and chop the hay and straw supplied to the horse. A little cut hay or chaff mixed with bruised oats prevents the animal from swallowing its food without thorough mastication. If, as alleged, bruised oats are laxative, the addition of a small proportion of beans will obviate that disadvantage.

Cooking Food.—It is certainly desirable to slice or pulp turnips and mangels, but it does not seem necessary to cook such soft and easily masticated food as is the practice with some stock-feeders. Rape-cake should always be steamed and mixed with some such palatable food as locust-beans or molasses. Chaff and all other foods containing a large proportion of woody fibre are more digestible when cooked than in their raw state; and foods when inferior of their kind should always if possible be cooked.

Importance of a Mixed Food.—Experience has proved not only the advantage but the necessity of a mixed food to the healthy sustenance of the animal body. Hence the value of any vegetable production, considered as the *sole* food of an animal, cannot be accurately determined by the amount it may contain of any *one* of its ingredients, *all* of which together are necessary to build up the growing body of the young animal, and to repair the natural waste of such as have attained to their fullest size.

Hence the failure of the attempts that have been made to support the lives of animals by feeding them upon pure starch or sugar alone. These substances would supply the carbon perspired by the lungs and the skin; but all the natural waste of nitrogen, of saline matter, of earthy phosphates, and probably also of fat, must have been withdrawn from the existing solids and fluids of their living bodies. The animals, in consequence, pined away, became meagre, and sooner or later died.

So some have expressed surprise that animals have refused to thrive—have ultimately died—when fed upon animal jelly or gelatin alone, nourishing though that substance *as part of the food* undoubtedly is. When given in sufficient quantity, gelatin might indeed supply carbon enough for respiration, with a great waste of nitrogen; but it is deficient in the saline ingredients which a naturally nourishing food contains.

Even on the natural mixture of starch and gluten which exists in fine wheaten bread, dogs have been unable to live beyond 50 days, though others fed on household bread, containing a portion of the bran—

in which earthy matter more largely resides — continued to thrive long after. It is immaterial whether the general quantity of the *whole* food be reduced too low, or whether *one* of its necessary ingredients only be too much diminished or entirely withdrawn. In either case the effect will be the same—the animal will become weak, will dwindle away, and will sooner or later die.

The skill of the feeder may often be applied with important economical effects to the proper selection and mixture of the food he gives his animals generally, and at various stages of their growth.

It has been found by experiment, for example, that food which, when given alone, does not fatten, acquires that property in a high degree when mixed with some fatty substance; and that those which are the richest in the muscle-forming ingredients, produce a comparatively small effect unless they contain also, or are mixed with, a considerable proportion of fatty matter. Hence the reason why a stone of linseed has been found by some to go as far as two stones of linseed-cake; and why the Rutlandshire farmers find a sprinkling of linseed-oil upon the hay to be a cheap, wholesome, and fattening addition to the food of their cattle and horses.

Values of different kinds of Food.—It appears, as the result both of theory and of practice, that different kinds of food are not equally nourishing. This fact is of great importance, not only in the preparation of human food, but also in the rearing and fattening of stock. It has therefore been made the subject of *experiment* by many practical agriculturists, with the following general results:—

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1. If common hay be taken as the standard of comparison, then, to yield the same amount of nourishment as 10 lb. of hay, experiments on feeding made by different persons, and in different countries, say that a weight of the other kinds of food must be given which is represented by the number opposite to each in the following table :—

Hay, . . .	10	Carrots (white), .	45
Clover-hay, . .	8 to 10	Mangel-wurzel, .	35
Green clover, . .	45 ,, 50	Turnips, . . .	50
Wheat-straw, . .	40 ,, 50	Cabbage, . . .	20 to 30
Barley-straw, . .	20 ,, 40	Peas and beans, . .	3 ,, 5
Oat-straw, . .	20 ,, 40	Wheat, . . .	5 ,, 6
Pea-straw, . .	10 ,, 15	Barley, . . .	5 ,, 6
Potatoes, . . .	20	Oats, . . .	4 ,, 7
Old potatoes, . .	40?	Indian corn, . .	5
Carrots (red), . .	25 ,, 30	Oilcake, . . .	2 ,, 4

It is found in practice, as the above table shows, that twenty stones of potatoes, or three of oilcake, will nourish an animal as much as ten stones of hay will, and five stones of oats as much as either. Something, however, will depend upon the quality of the sample of each kind of food used—which we know varies very much, and with numerous circumstances; and something also upon the age and constitution of the animal, and upon the way and form in which the food is administered. The skilful rearer, feeder, and fattener of stock knows also the value of a change of food, or of a mixture of the different kinds of vegetable food he may have at his command—a subject we have considered in a previous section.

Concluding Remarks.—In the little work now brought to a close, the reader has been presented with a brief, but, it is hoped, plain and familiar sketch

of the various topics connected with Practical Agriculture, on which the sciences of Chemistry, Geology, and Chemical Physiology are fitted to throw the greatest light.

We have studied the general characters of the organic and inorganic elements of which the parts oi plants are made up, and the several compounds of these elements, which are of the greatest importance in the vegetable kingdom. We have examined the nature of the seed—seen by what beautiful provision it is fed during its early germination—in what forms the elements by which it is nourished are introduced into the circulation of the young plant when the functions of the seed are discharged—and how earth, air, and water are all made to minister to its after-growth. We have considered the various chemical changes which take place within the growing plant during the formation of its woody stem, the blossoming of its flower, and the ripening of its seed or fruit, —and have traced the further changes it undergoes, when, the functions of its short life being discharged, it hastens to serve other purposes, by mingling with the soil, and supplying food to new races. The soils themselves in which plants grow, their nature, their origin, the causes of their diversity in mineral character and in natural productiveness, have each occupied a share of our attention—while the various means of improving their agricultural value by mechanical means, by manuring or otherwise, have been practically considered and theoretically explained. Lastly, we have glanced at the comparative worth of the various products of the land as food for man or other animals, and have briefly illustrated the prin-

ciples upon which the feeding of animals, and the relative nutritive powers of the vegetables on which they live, and of the parts of animal bodies themselves, are known to depend.

In this short and familiar treatise it has not been sought so much to *satisfy* the demands of the philosophical agriculturist, as to *awaken* the curiosity of the less-instructed reader—to show him how much interesting as well as practically useful information Chemistry and Geology are able and willing to impart to him, and thus to allure him in quest of further knowledge and more accurate details of subjects of which the foregoing is only a brief outline.

APPENDIX.

RECENT EXPERIMENTS WITH PHOSPHATIC MANURES.

THE following is a brief account of the experiments with artificial manures—chiefly phosphatic—recently made by the Aberdeenshire Agricultural Association, with the assistance of an able agricultural chemist, Mr T. Jameson, Fellow of the Institute of Chemistry. There are also given the results of some experiments made by Dr Voelcker and others, with the object of determining the relative value of different kinds of phosphates. The Society selected five sites, containing each about 2 acres, and from 10 to 20 miles apart. The soils varied from strong clay to sandy loam, with elevations of from 100 to 400 feet above the level of the sea, from which the sites were distant from 2 to 30 miles. Experience of plots of various sizes had led to distrust of results from large plots, and to the adoption of plots 34 ft. 7 in. by 11 ft. 3 in., or $\frac{1}{112}$th of an acre—a size which gives sufficient growing space for 300 turnips, and is convenient for calculation purposes, as it bears the same relation to the acre as the lb. bears to the cwt. Hence the

number of lbs. of manure applied, or crop reaped, per plot, signifies also the number of cwts. per acre. This size is highly recommended, both for insuring equality of soil, conditions of cultivation, and accuracy of work, admitting as it does of every operation being performed under the eye of the chemist. A fence surrounds each station, and each plot is marked off by a broad deal board driven down edgeways till about level with the soil. The rotation in Aberdeenshire is remarkably uniform—viz., turnips, cereals, grass (2 or 3 years), and cereals. All the manure is generally given to the first-named crop. Adopting this system, it was decided to commence the experiments with turnips. It was also decided to limit the inquiry to phosphates and nitrogen, which (in a variety of forms) are the chief ingredients of ordinary manures; but recognising the necessity for insuring that the crop should not be stunted by dearth of the other essential ingredients of plant-growth, a mixture of potassium chloride, magnesium sulphate, and common salt was applied in equal quantities to all the plots. This point is insisted upon as essential in all reliable experiments, and it is regrettable that most experiments are useless by inattention to it. The quantity of phosphate given was at the rate of 100 lb. of phosphoric anhydride per acre in every case where dissolved phosphate was used, and 150 lb. when undissolved. In this way nearly equal outlays were made, and, at the same time, allowance was made for the assumed greater diffusion of the soluble form. Nitrogen, when used, was given at the rate of 22¼ lb. per acre—*i.e.*, about the quantity contained in 1 cwt. sulphate of

ammonia, and nearly the quantity (associated with 150 lb. phosphoric anhydride) found in bones. To arrive at these proportions precisely, all the manures used were analysed. Analyses—both mechanical and chemical—were also made of the soils and subsoils of each station. The mechanical and chemical treatment of each of the five stations was identical; and as each experiment was done in duplicate, ten answers were thus obtained to each question put. One of the stations (Cluny) was rather rich—it yielded 16 tons turnips, without giving any phosphates. The average of the five stations without phosphates was 10 tons—the addition of nitrogen made little difference; but when ground coprolite (without any nitrogen) was given, the crop was raised to 16 tons. Omitting Cluny station, the average results of eight experiments with each manure are as follow:—

No phosphate, ...	8 tons.
Undissolved coprolite, ...	16 ,,
Undissolved bone-ash, ...	17 ,,
Dissolved coprolite, ...	18 ,,
Dissolved bone-ash, ...	18 ,,

A place had thus to be given to insoluble mineral phosphate (coprolite) altogether different from that which had been generally assigned to it, and which was that it had little or no effect on plants, and hence no manurial value; whereas, compared with the insoluble animal phosphate (bone-ash), the result was nearly the same. Although, on the final average, bone-ash gave about 1 ton more, it was evident that this difference was not to be reckoned on, as in four out of the ten comparisons mineral phosphate stood even higher than animal phosphate.

The Association therefore decided to publish the following conclusion :—

"That phosphates of lime decidedly increase the turnip crop; but that farmers need not trouble themselves to know whether the phosphates are of mineral or of animal origin."

Comparing these two insoluble substances (coprolite and bone-ash) with the same substances after being made soluble by sulphuric acid, an increase over the insoluble was got, but on the average this superiority was under 10 per cent; while at two of the stations the results were identical, and at a third the insoluble gave a higher yield than the soluble form. Insoluble *mineral* phosphate, as stated above, had generally been considered valueless as a manure, and as even *animal insoluble* phosphate had been regarded as only *one-half* the value of soluble phosphate, a modification of these views seemed necessary. The Association gave their conclusions from forty experiments in the following tentative form :—

"That soluble phosphate is not superior to insoluble phosphate to the extent that is generally supposed."

Nitrogen used alone (as sulphate of ammonia and as nitrate of soda) was productive of little or no increase; but when used along with phosphate, the crop was raised from 3 to 5 tons. An exception to this was when the nitrate was used with *insoluble* phosphate. So also, when nitrogen was used in the organic form in which it exists in bone, no increase was found. Apparently this was due to the rough state of division (¼ in.), for when the bone was in that very fine state of division attainable by steaming the

bones before grinding them, the increase was maintained, notwithstanding that the proportion of nitrogen was reduced by this steaming.

When the bulbs were analysed, it was found that those manured with nitrogen, in addition to phosphates, contained very uniformly a *smaller proportion of solid matter* than those manured with phosphate alone; allowance being made for this, the increased gain by nitrogen over phosphate mostly disappeared. The Association therefore concluded, from the combined teachings of a hundred experiments in which nitrogen was used—

"That nitrogenous manures have little effect on turnips used alone, but when used along with insoluble phosphates, increase the crop; that the addition of nitrogen to soluble phosphates does not seem to increase the solids or dry matter in crop; that there is no material difference between the effects of equal quantities of nitrogen in nitrate of soda and in sulphate of ammonia; that fineness of division seems nearly as effective in assisting the braird and increasing the crop as the addition of nitrogenous manures. Hence the most economical phosphatic manure for turnips is probably insoluble phosphate of lime, from any source, ground down to an impalpable powder."

During the four subsequent years the Association repeated the original experiments on the same kind of crops, and on some others.

The following year a departure was made from the original intention of carrying out the rotation. As some of the manures acted slowly, their total effects were thought to be ascertained by continuing to grow

turnips in the land manured by them, but without the further application of the particular manures. That is, an application of a phosphate having been made to a crop of turnips, one or two other crops were subsequently grown on the same plots without further use of phosphates. In the third year the alkaline precautionary mixture was given. The result was the natural one of equalising the yield according to the rapidity of action of the manures. The difference in *ready* action was shown in the results of the *first* year.

Highest results were after	Phosphates with nitrogen. Steamed bone-flour.
Lowest results were after	Roughly crushed bone. Coprolite.

The *slower* acting and more *lasting* manures were conspicuous in the *third* year, in which the

Highest results were after	Steamed bone-flour. Roughly crushed bone. Coprolite.

All the others were lower, and nearly equal with one another.

The *most productive over the three years* were thus found :—

Highest	Steamed bone-flour. Dissolved phosphate and nitrogen. Roughly crushed bones.
Medium	Undissolved phosphate and nitrogen. Dissolved mineral phosphate. Undissolved mineral phosphate.
Lowest	Dissolved animal phosphate. Undissolved animal phosphate.

Taking into account the watery character of the bulbs when manured with nitrogen, along with the very high results from steamed bone-flour, and with the fairly good results from coprolite,—and the fact that it provides phosphate at half the price charged for phosphate in other substances,—the Association decided the following year to try calcium phosphate in steamed bone-flour and coprolite (costing 28s.) against an equal quantity of phosphate in the usual manures, viz., crushed bones and dissolved bones (costing 42s.)—in both cases with an equal quantity of farmyard manure. The results were practically the same.

The plots being now much reduced in phosphates, a repetition (with some modifications) of the original phosphatic manuring was made; the season was unusually bad, the crops were very poor, but the former relative effects of the different forms of phosphates were maintained. In the fifth season the manuring (phosphatic and alkaline) was again carried out, and some remarkable results were obtained. Two of the five stations had been closed to permit the opening of two new stations in England. At one of the remaining three (Aboyne), all the turnips were healthy; but while the action of the different forms of phosphates was relatively the same, the addition of nitrogen to phosphate produced a very large increase—the quantity of nitrogen originally present in the soil having evidently become scarce. At the other two stations *disease prevailed*, but the remarkable feature was presented that the disease was aggravated invariably in the plots to which dissolved manures had been given. A variety of collateral experiments

combined to show that there is an association of the disease with a *fungus* on the one hand and with *sulphur* on the other, for which the explanation is thrown out that the sulphur assists the formation of the volatile sulphurous oil, by which the turnip is recognised from other plants, thus attracting the turnip-seeking fungus and providing sustenance for its growth and development—at the same time, by the associated soluble phosphate causing such a rapid growth as to produce a weakly and easily vanquished plant.

When the rotation system was departed from, it was only to begin it anew on fresh ground within the enclosure which had been equalised and exhausted by a hay crop unmanured. The original experiments on the former plots were here repeated under more trying conditions, and with certain modifications—chiefly, that the quantities of insoluble phosphates were reduced to 100 lb., *i.e.*, to the same as the soluble phosphates. The light manuring and the reduced state of the land naturally resulted in moderate crops, but they confirmed the original conclusions. This crop was followed by oats, the manure being repeated. In regard to this crop, as far as phosphates were concerned, there was no material difference between the mineral and animal forms; while soluble phosphate showed 10 to 15 per cent superior to insoluble phosphate. The addition of nitrogen, however, was followed by a remarkable increase, and this increase was not due to excessive water, as had been found in turnips. Following the oats came hay (grass and clover), without further manuring. This crop was remarkably abundant—a fact attributed to the repeated applications of potash, and to good

mechanical condition of soil. As far as phosphates were concerned, the results were increased by about 20 per cent by their application, and the results were the same, indifferently of the kind of phosphate used. The poorest crops were those which had got nitrogen the previous year—due, it was considered, to the preceding heavy oat crops having reduced the available mineral food.

In 1864 the editor of this work sent an essay to the Highland and Agricultural Society of Scotland, showing results of the application of phosphatic manures to mangels. In these experiments it was found that finely ground coprolite phosphate, weight for weight of actual phosphoric anhydride, produced heavier crops than coarse bone-ash, and that it was exceeded in its effects by an equal amount of phosphoric acid in the shape of dissolved coprolite. The general results of the experiment proved that coprolites ground very finely were a powerful fertiliser. Although the Society awarded a medal to the author, they did not publish his paper.

The 'Journal of the Royal Agricultural Society of England,' vol. xvii., part i., 2d series, 1881, contains four papers showing the results obtained from the application of ground phosphates to crops. The first of these papers is contributed by Dr Voelcker, and describes the results of the application of finely ground coprolites, redonda phosphate, precipitated phosphate, and raw bone-meal, as compared with the effects produced by the use of dissolved coprolites and other manures. About the same money's worth of each manure was used. The ground coprolites produced an increase of 3½ tons of swedes per acre,

as compared with unmanured plots; redonda phosphate, 5½ tons; bone-meal, 1 ton 13 cwt.; precipitated phosphate, 5 tons 6 cwt.; dissolved coprolites, 6 tons 13 cwt.; and dissolved bones, 5 tons 13 cwt. It will be seen that there was very little difference between the action of the redonda phosphate and the dissolved coprolites, whilst the increase produced by the coprolites fell considerably short of that caused by the soluble phosphate. Redonda phosphate is composed of phosphates of iron and aluminum, and is not considered to be worth much by the artificial-manure manufacturer. These experiments are, on the whole, in favour of raw phosphates; for after their effect on the turnip crop had been produced, a larger amount of them was available in the soil for following crops. There are, of course, greater quantities of phosphoric acid in 10 cwt. of redonda phosphate and 5 cwt. of coprolites than in 3½ cwt. of dissolved bones, or 5 cwt. of coprolite superphosphate. The soil of the plots to which some of the ground coprolites and the bone-meal were applied was inferior to that of the other plots. Ten tons of dung and 6½ cwt. of coprolites gave as good results as 20 tons of dung, and better than 10 tons of dung and 5 tons of dissolved coprolites. According to Mr R. Vallentine, swedish turnips grown in a soil to which no dung had been applied for 31 years, yielded a crop at the rate of 8 tons per acre; the addition of 20 tons of dung caused an increase of 8 tons; whilst the addition of 10 tons of dung augmented the crop to the extent of 2½ tons, 3 cwt. of coprolites added 1 ton, and 9 cwt. of coprolites 1⅛ ton to the crop.

On the other hand, 3 cwt. of dissolved coprolites increased the crop by $3\frac{3}{8}$ tons. In these experiments the coprolites do not seem to have produced a decided effect upon swedish turnips.

According to Mr R. Vallentine, whilst two plots unmanured gave 6 tons and $7\frac{1}{10}$ tons of swedes per acre, the addition of the following manures caused a large increase in each case :—

4 cwt. of bone-dust, . . .	$10\frac{1}{2}$	tons swedes.
$7\frac{1}{2}$,, coprolites	$10\frac{1}{4}$	,, ,,
5 ,, dissolved coprolites . .	$12\frac{1}{20}$	,, ,,

In 1880 the Rochester Farmers' Club experimented with insoluble and soluble phosphates. They found that two plots of unmanured land yielded $12\frac{13}{20}$ tons of swedish turnips per acre; two plots manured with 10 cwt. of coprolites gave $15\frac{1}{12}$ tons; 1000 lb. of dissolved coprolites averaged in the two plots 16 tons 13 cwt.; 530 lb. of finely crushed bones, $13\frac{18}{20}$ tons. Tops and roots were included in the weighings.

Some references to Messrs Lawes and Gilbert's experiments on root-crops may be found interesting in this place. In 1875 sugar-beet was grown with different manures, and without manure, on five different plots, and with the following results :—

Without manure, 1874 and 1875 (farmyard manure in '71, '72, '73), ...	$17\frac{1}{4}$ to $22\frac{7}{20}$	tons
$3\frac{1}{2}$ cwt. superphosphate (with farmyard manure, '71, '72, '73), ...	$15\frac{11}{20}$ to $20\frac{9}{20}$	,,
Without manure (1846 and since), . .	$5\frac{9}{20}$ to $14\frac{1}{20}$	,,
$3\frac{1}{2}$ cwt. superphosphate, 500 lb. sulphate potass, 200 lb. each of common salt and sulphate of magnesium, ...	$5\frac{9}{20}$ to $12\frac{14}{20}$	,,
$3\frac{1}{2}$ cwt. superphosphate, ...	$5\frac{11}{20}$ to $13\frac{7}{20}$	,,
$3\frac{1}{2}$ cwt. superphos., 500 lb. sulph. potass, .	$5\frac{4}{20}$ to $12\frac{8}{20}$	,,

3½ cwt. superphos., 500 lb. sulph. potass and ammonia-salts, '71, '72, '73, . . .	$5\frac{11}{20}$ to $11\frac{17}{20}$ tons.
Unmanured, 1853 and since; previously part unman., part superphos., ...	$4\frac{3}{4}$ to $12\frac{1}{10}$,,

In 1871, 14 tons of farmyard manure produced from $18\frac{3}{20}$ to $28\frac{9}{10}$ tons of this valuable root, and from $3\frac{1}{4}$ to $6\frac{19}{20}$ tons of leaves. The roots contained on the average fully 17 per cent of dry matter.

[EXPERIMENTS

Manures per acre per annum.	Series 1.		Series 2. As Series 1, and cross-dressed with 550 lb. nitrate soda.		Series 3. As Series 1, and cross-dressed with 400 lb. "ammonia-salts."		Series 4. As Series 1, and cross-dressed with 2000 lb. rape-cake and 400 lb. "ammonia-salts."		Series 5. As Series 1, and cross-dressed with 2000 lb. rape-cake.	
First Season, 1876. *Seed dibbled, May 22-26. Crop taken up, Nov. 3-17.* *Produce per acre—Roots.*										
	tons.	cwt.	tons.	cwt.	tons.	cwt.	tons.	cwt.	tons.	cwt.
Farmyard manure (14 tons)	19	12	25	2	29	19	31	9	24	9
Farmyard manure (14 tons), and 3½ cwt. superphosphate (1)	19	13	27	13	29	8	30	18	29	19
Without manure (1846 and since)	6	10	20	13	14	3	19	19	17	4
3½ cwt. superphosphate, 500 lb. sulphate potass, 200 lb. each common salt and sulphate magnesium	8	8	25	1	19	19	30	8	25	8
3½ cwt. superphosphate	7	10	21	0	13	10	17	2	17	17
3½ cwt. superphosphate, 500 lb. sulphate potass	6	16	21	2	17	15	26	8	20	10
3½ cwt. superphosphate, 500 lb. sulphate potass, 36½ lb ammonia-salts (2)	8	13	22	11	19	2	27	2	20	12
Unmanured, 1853 and since; previously part unmanured, part superphosphate	5	9	15	16	11	17	18	2	15	12
Farmyard manure (14 tons), 3½ cwt. superphosphate (3)	....		....		25	14	....		....	
Fifth Season, 1880 *Seed dibbled, April 22-23 (Plot 9, April 24). Crop taken up, Nov. 2-11.* *Produce per acre—Roots.*										
Farmyard manure (14 tons)	18	11	26	8	25	4	27	3	27	5
Farmyard manure (14 tons), and 3½ cwt. superphosphate (1)	17	8	27	16	25	15	26	0	27	9
Without manure (1846 and since)	4	10	14	0	9	17	11	4	12	6
3½ cwt. superphosphate, 500 lb. sulphate potass, 200 lb. each common salt and sulphate magnesium	5	17	23	6	19	14	30	11	24	4
3½ cwt. superphosphate	5	3	18	6	9	18	12	9	14	8
3½ cwt. superphosphate, 500 lb. sulphate potass	4	15	21	10	18	12	27	4	21	8
3½ cwt. superphosphate, 500 lb. sulphate potass, 36½ lb. ammonia-salts (2)	7	0	21	10	19	6	26	0	23	2
Unmanured, 1853 and since; previously part unmanured, part superphosphate	4	0	11	14	5	19	12	4	12	1
Farmyard manure (14 tons). 3½ cwt. superphosphate (3)	....		....		20	19	....		....	

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